

MATHO:

OR, THE

Cosmotheoria Puerilis,

A

DIALOGUE.

IN WHICH

The first Principles of PHILOSOPHY and ASTRONOMY are accommodated to the Capacity of young Persons, or such as have yet no Tincture of these SCIENCES. Hence the Principles of Natural Religion are deduced,

Translated, and enlarged by the AUTHOR.

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Nam corpus hoc animi pondus & poena est: Premente illo urgetur, in vinculis est, nisi accessit Philosophia, et illum respirare rerum naturæ spectaculo iussit. — Vetas me cælo interesse, id est, jubet me vivere capite demisso. Seneca.

L O N D O N:

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The Eighth CONFERENCE.

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Seventh CONFERENCE.

Matho and Philon resume the Discourse concerning the Planetary System. Of the compound motion of the Satellites round their Primary Planets, and with their Primaries round the Sun. A Body, that it may revolve about a Center, (which Center itself revolves about another Center) must indefinitely be urged by four different Forces; two with respect to each Center. That each of these Forces is constantly impressed (or at least successively renewed) by an im-

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material Power, and not owing to one original impulse. Of that Limit between the Sun and any Primary Planet, where their attractive Forces are equal. That any Secondary Planet must revolve within that Limit: or, the Orbit of the Secondary must lye between that Limit and its Primary.

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XCII. M. **I** AM come back to you, Philon, full of a grateful Sense of your Favours; for I reckon it a Happiness that I address'd my self first to you.

P. What sort of an Introduction is this; or why do you reckon that such a Happiness?

M. Because now I think I understand some things of no small Consequence, which before I knew nothing of.

P. How much of this do you owe to me?

M. The whole certainly.

P. Your Reckoning seems to be wrong.

M. How comes it to pass then that I now understand what formerly I was quite ignorant of?

P. When one has to deal with a Person of good natural Sense, *Matho*, the whole Secret

cret of Teaching consists in putting proper Questions to him. It often happens, that by our seeming to doubt of plain things, we provoke him to defend the Truth he knows, and to discover the Consequences of it, which formerly he did not attend to: This is all the poor Service I have done you.

M. We are more effectually instructed, I believe, by such *pretended Doubting*, than by direct and ready answers; as this Method interests us more in the Enquiry.

P. But it is not every one, I can assure you, who is capable of being instructed in this manner.

M. And yet I have heard, some of the *ancient Philosophers* were of Opinion, that any Person might be instructed, by putting Questions to him in a natural and dependent order:

P. Yes; those Philosophers, who supposed that all the Knowledge we acquire here, is only *Reminiscence* of what we understood in a former State: If so, some of us did not, it seems, understand much then, and remember less now.

M. Nay, *Philon*, to leave joking, if I might dispute the point with you, I think I could shew this to be true on your own Principles.

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P. On my Principles?

M. Yes: For since you allow that we are purely passive in perceiving the Agreement or Difference of our Ideas, after they are carefully formed, and clearly seen; it will follow that any one must necessarily see the Truth, provided his *Teacher*, by proper and natural Questions, can excite in his Mind just Ideas of the Point in Agitation between them.

P. Is this the Subject, which, when we parted, you said we were to talk upon in our next Conference?

M. I desist then: But remember, you have the better of me in this Argument, not by your Reasons, but by your Authority. — Now to come to the Particulars concerning which I wanted to be informed: You said, in describing the Bodies in our solar System, that the *Moon* rolled twelve or thirteen times about the *Earth*, while that was carried round the Sun in its annual Course. This Motion of the *Secondary Planets* round their Primaries I do not well understand: I cannot conceive how the *Moon* should be carried along with the *Earth*, and roll about it at the same time. Besides, I would know why the Moon revolves about the Earth at all; and

and not rather about the Sun separately, as a Primary Planet. What Reason can be assigned, why *Jupiter's* four Moons, or *Saturn's* five, do not immediately direct their Course about the Sun, the common Center of the whole System; instead of regarding those other Planets as the Centers of their Motions?

P. You know, as *Satellites*, or *Guards*, they must be obliged to a constant personal Attendance.

M. Pray, *Philon*, leave off jesting, when we come to speak of serious Matters. You promised likewise to shew me how the powerful Action of the Sun, through the whole System, does not disturb the Motions of these *lesser Systems*.

P. Pardon me, *Matbo*; I was not so rash neither to make such a Promise. I did not refuse to discourse with you on any Subject you should propose; because you said, while we conversed familiarly, and without Reserve, many things offered to us, which otherwise would not have occurred: But I dare not pretend to give you Satisfaction in those things. The *compound Motion* of the *Secondary Planets* is one of the most intricate Points I know, and hardest to be conceived:

Nor are the other things you mention less, but rather more difficult.

M. I am aware of the Difficulty of the first Particular: But this whets my Curiosity the more.

P. To give you what Assistance I can then: With respect to the Motion of the Secondary Planets round their Primaries, you saw before, or rather found out from Arguments of your own, That the celestial Bodies have their globular Figure from the mutual Attraction between all their Parts; and that this Attraction does not cease at their Surfaces, but prevails through a certain spherical Space round them, according to the Quantity of Matter each of them contains. Hence comes the *Relative upward and downward* belonging to every particular Planet in our System; from which Relation this Attraction is called Gravitation; for Gravitation is only a relative Term. And from this *particular Attraction* it is, that the Satellites roll round their Primary Planets, the same Way, and by the same Laws, as the Primary Planets do round the Sun: Therefore where there are more Satellites than one, the Squares of their periodical Times, about the great Planet, are as the Cubes of their Distances

Distances from it; just as it is with respect to the Times of the Primary Planets about the Sun, and their Distances from him.

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XCIII. *M.* This I remember, and see plainly enough that their circular Motion must be caused by a gravitating and projectile Force constantly acting upon them: This holds universally in all Bodies revolving about a center in free Spaces. But then, how do you combine with this Motion that other, whereby they are carried along with their *Primaries* round the Sun? Or is the Attraction of their *Primaries* strong enough to carry them thus along through their own larger Orbits, without any other Force impressed?

P. By no means. — But to help your Imagination in this Affair, suppose at first that the Sun is quite absent, and that the *Primary* remains as an immoveable central Body instead of the Sun.

M. What then?

P. In this Case, the gravitating and projectile Forces being impressed on the Satellite, you see it must revolve about its *Primary* (now standing still) just as the *Primary* it self revolved about the Sun before.



M. The same way indeed; for there is no Difference between the two Cases.

P. Imagine then that the *Primary* is impelled straight forward, together with its *Satellite*; a Force being impressed on both by *some skilful and mighty Hand*, always in parallel Directions; while in the mean time the two former Forces (namely, the *gravitating* and *projectile*) act constantly on the *Satellite*, as before this last Force was impressed: And consider then what will be the Result.

M. The *Satellite* is now urged by three Forces: *This last* carries it foreward in a parallel Direction with its *Primary*; and by the *two first* it must still roll round its *Primary*, I suppose, as if neither *that* nor itself were impelled forward. But there is something here which I do not fully conceive.

P. Leave particular Niceties 'till another time, and endeavour at first only to get a general Notion of the Case. In the main it is as you say: For we may be sure that no one of the *three Forces* impressed can be without its Effect, more than if they had been impressed separately on three different Bodies. Now keeping these things in your Mind, imagine the Sun to be brought back to his
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Place again ; and then consider what will ensue.

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M. The Sun being replaced, Gravitation towards him must begin to act on both the *Primary* and *Secondary* ; and the excursory or projectile Force (by which, to wit, both were impelled straight forward in parallel Directions) was impressed on both before. Whence, since they are, by Supposition, at a due Distance from the Sun ; so that neither his Attraction nor their excursory Tendency can overcome the one the other ; they must begin, I think, to roll round him ; while in the Interim the Satellite continues to perform its lesser Rotations about its *Primary*, as before.

P. You trace out the Consequences very distinctly ; and from this you will be able to form a Notion, how such a complex Motion of the Satellite is effected.

M. I conceive it indeed in some measure : But as there are four different Forces constantly impressed here on the Satellite ; tho' I easily apprehend how it should be attracted to two different Centers ; yet I can hardly reconcile in my own Mind the two different projectile Forces impressed on it ; one with respect to its revolving about its own *Prima-*
ry,

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ry, and the other with respect to its revolving along with *that* about the Sun; which must so often interfere and oppose each other. Pray might we not suppose that the larger Planet, while it moves on in its own Orbit, attracts the Satellite or lesser Planet, so strongly, as to carry it along without any other Force impressed upon it?

P. By no means, I say: We must not make Suppositions contrary to the Reality of Things. If we take our *Earth* and *Moon* as an Example, we shall find *that Supposition* inconsistent with the Nature of the Moon's compound Motion: Nor is there any way of getting free from the constant Impression of these four different Forces (and therefore of the two different projectile Forces) upon her at once.

M. Then I see the Truth of what you said, That the compound Motion of the Satellites is harder to be conceived than any thing I have hitherto met with. But how does this constant Impression of two different projectile Forces appear from the Example of the *Earth* and Moon?

P. We observed before, if the Distance of the Earth from the Sun be 21000 of its own Semi-diameters, its Motion in its annual Orbit

Orbit must be at the rate of 1000 Miles in a Minute: And it is certain that the attractive Force of the Earth upon the Moon could only draw her a little more than 16 Feet in a Minute. Now when the Moon is in her last quarter, that is, directly behind the Earth in its annual Orbit, she is not left behind the Earth, but moves with equal Velocity, or after the rate of 1000 Miles in a Minute; and yet could only move in the same Direction so small a Space as 16 Feet by the attractive Force of her Primary Planet.

M. This is an enormous Difference!

P. It is indeed; and though we should suppose the Distance of the Earth from the Sun less, and therefore its Velocity less; the Difference would still be enormous.—— In advancing from this Point of her Orbit to her Conjunction with the Sun, she is there as far forward with respect to the annual Course of the Earth, as the Earth itself is.

M. I understand; for she is now got between the Earth and the Sun.

P. Therefore in about seven Days Time, besides moving at the rate of 1000 Miles every Minute, she hath gained upon the Earth nearly 240000 Miles, or the whole Semi-diameter of her own Orbit.

M. It

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M. It is so.

P. But this is the Effect of a different projectile Force; in her own Orbit, to wit: For the Attraction of the Earth could not have brought her so far forward. This Attraction (as has been said) could only have drawn her 16 Feet in any Minute, and that toward the Center of the Earth: Whereas here (considering her Motion as parallel to the Earth's) she hath moved about 22 Miles in a Minute, over and above the 1000. For 240000 Miles in 7 Days 9 Hours comes much to this.

M. Go on. This is plain.

P. In moving on to the first Quarter after the Conjunction, she is now got directly before the Earth in its annual Course, as about 14 or 15 Days before she was behind it: Therefore she has gained on the Earth another 240000 Miles. And in this Part of her Orbit she moves on in the annual Course 1000 Miles in a Minute; directly contrary to the Earth's Attraction.

M. I see it clearly.

P. In ascending to her Opposition with the Sun, when she appears full, she hath lost 240000 Miles, with respect to the Velocity of the Earth's Motion; or the Earth is as far

far advanced in the annual Course as she : Seventh
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And in returning to the first Point again,
that is to her last Quarter, she hath lost
240000 Miles more: The Reason of which
is easily seen. In all these Cases, her rapid
Motion in attending the Earth, you find, is
not in the least affected by her Gravitation
towards it. That does no more than ba-
lance her centrifugal Force in her own
Orbit.

XCIV. *M.* You have now fully con-
vinced me of the Necessity of impressing
both these projectile Forces on the second-
ary Planet, especially the *first*, with respect
to its Motion about the Sun, always in a
parallel Direction to the Motion of its Pri-
mary; and at the same Time you have
raised in me an Admiration of a Motion so
complex, and skilfully maintained by a con-
stant Variation.

P. Let me know what you understand
by its being maintained by a constant Varia-
tion?

M. I am afraid I shall not be able to
express clearly a Thing which in its own
Nature is not easy to be conceived.

P. It

P. It sometimes so happens indeed: But in such Cases Allowance is to be made, and the Words are supposed to convey more than they express.

M. While the Moon here moves in her own Orbit round the Earth, a prodigious Force is constantly impressed upon her, which hath no Relation to her Motion in that Orbit, but to her moving in a parallel Direction with the rapid Motion of that very Body, about which she must at the same Time revolve. Now that this parallel Motion to, and periodical Motion round the same Body, should be made consistent, appears to me wonderful above Expression; and requires a constant, and nicely adjusted Variation of this parallel Impression in every Point of her Orbit.

P. Go on; I conceive what you say very easily.

M. As the Motion of the Earth is in a circular Orbit, an Impression of Force parallel to the Direction of such a Motion must be changed, and therefore renewed every Minute, as the Direction of the Motion itself is changed in every Point. When we look round, there is no Attraction here, nor stated mechanical Law (supposing Attraction

traction were *mechanical*) to supersede this constant Impulse in a different Direction: For you shewed abundantly just now, that the attractive Power of the Earth doth not in the least contribute to it. And this *parallel Impression* itself is to supply the Place of a projectile Force; as we saw, when it was first impressed on the *Primary* and *Satellite*, before the attractive Force of the Sun was supposed to act. So that the Impression of this Force (as was said) is to be changed, and therefore renewed every Minute, by an *immechanical Cause* * ———
Besides, while the Moon moves regularly round her *Primary*, in her proper Orbit; sometimes she gets before it, sometimes she returns back, anon she overtakes it; and

* Left it should be here surmised, that the attractive Power of the Sun may be sufficient so to affect *this Force* impressed on the Moon, as always to bend her Motion into a Direction parallel to the Orbit of the Earth, in a mechanical Manner, and without a new Intervention of Divine Power; let it be considered that if, in the Conjunction, the Sun's Attraction were thus sufficient to bend the Moon's Motion into a Direction parallel to the Earth's Orbit, (that is, into a concentrical Circle;) the Moon could never turn up again toward the Earth's Orbit, or leave that Circle. And if the Sun's Force be not sufficient to give her Motion such a Bent in the Point of Conjunction, it cannot be sufficient when the Moon is at a greater Distance.

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often she moves obliquely, or cross-wise. Hence this *parallel Impression* must sometimes be stronger, sometimes weaker, and the Quantity of it constantly varied, according to the different Part of her Orbit she moves in; or there is an inconceivably nice Composition of two different Impulses (the projectile Force, I mean, in her own Orbit, and this *parallel Impression*) whereby they sometimes conspire, are sometimes directly opposite, and often the one is made side-wise to the other. When their Directions conspire in the Conjunction, what separates them again? When they are contrary in the Opposition, what renews the lesser Force which is once quite destroyed? When the Directions are oblique, what preserves both Forces entire? There is nothing here like the *Axiom* you once told me of, *That a Body partakes of the Motion of its Place.* The Place of the Moon's Orbit is pure Space, which can neither be moved, nor impress a Force on any Body moving in it. From this it appears to me that not only the *parallel Impression*, but the Moon's projectile Force in her own Orbit, is still preserved the same, not from any mechanical Cause, but the constant

constant Action of the Deity. And since both these Forces are always impressed, or renewed, in such due Proportion that the one of them no more disturbs the other (in their Effects I mean) than if it were not impressed, I cannot enough admire this new Instance of the Divine Power and Wisdom in the Motions of these secondary Planets.

P. You have expressed this complex Appearance, *Mathe*, as clearly to my Apprehension as the Nature of the Thing will allow. In the *Conjunction* the Moon's Motion in her own Orbit conspires with this parallel Impression, and adds to its Celerity; in the *Opposition* her menstrual Motion is contrary to the other, and retards it; in all other Points of her Orbit they are oblique, less or more, and affect each other accordingly. But whether you conceive that the *parallel Impression* is made sometimes stronger, sometimes weaker; or that both Forces are still kept up to the same Quantity; we must still have Recourse to the immediate Power of the Deity, and give up all Explications by mechanical Causes. If the *parallel Impression* on the Satellite were not incessantly renewed in a different Direction,

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according to the circular Orbit of the *Primary*, these two could not keep together in one System: Or if the Moon's proper projectile Force were not constantly renewed after the Opposition, she could no longer roll about the Earth. For in that Point the weakest Force must be destroyed.

M. And this constant Miracle becomes manifold where four or five Satellites revolve about the same primary Planet: So that the Mind, which can hardly conceive this wonderful Adjustment of Forces in the simple System of the Earth and Moon, is quite confounded with the Variety of them in the more complicated Systems of *Jupiter* and *Saturn*.

P. And what is still more wonderful, *Matho*, this constant renewing of the *parallel Impression* will not be peculiar to the *Satellite* alone; but common to it with its *Primary*; if the secondary Planet does not precisely revolve about the Center of its *Primary*, but together with the *Primary* rolls about a certain Point between them, called their *common Center of Gravity*. In this Case the tangential or projectile Force of the larger Planets, which hitherto we have supposed to be owing to one original Impulse,

Impulse, given them at the Beginning of their Motions, will as much require a constant Variation of Impression, as that of the *Secondaries* themselves.

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XCV. *M.* Pray explain this Particular; for I am quite a Stranger to what you call the common Center of Gravity of two Bodies.

P. In Truth I'm afraid lest it should fatigue your Imagination too much, which cannot now be so brisk and ready as when we began: And this is no easy Speculation to one who has never heard of a Center of Gravity before.

M. If I do not understand what you say I shall be no wiser than if you had said nothing at all.

P. You must know then that the Center of Gravity of two Bodies (not to speak of more) is such a Point between them, about which if both roll, their centrifugal Forces will be equal, or balance each other; so that neither can carry off the other by its stronger Tendency to recede from the Center of its Motion. And therefore this Point is so much farther distant from the Center of the lesser Body, as the Quantity

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of Matter in the other is greater: or (which comes to the same Thing) it is so much nearer the Center of the greater Body, as the Quantity of Matter in the other is less.

M. Give me an Example of this?

P. If the Quantity of Matter in the Earth be forty Times more than that in the Moon, their common Center of Gravity will be forty Times farther distant from the Center of the Moon, than from the Center of the Earth; that her larger Swing in moving round this Point may make up what she wants in Matter to balance the centrifugal Force of the Earth, and hinder her from being drawn away. For a fortieth Part of the Matter with forty Times the Celerity will be equal to forty Times the Matter with once the Celerity. Therefore if we suppose the Distance between the Centers of the Earth and Moon divided into forty-one equal Parts, their common Center of Gravity will be forty of those Parts distant from the Center of the Moon, and only one of them distant from the Center of the Earth.

M. I think I have a Notion of this from some Sort of Balances I have seen; where
a Weight

a Weight half as great only as another, was yet a counter-poise for that other, provided it were placed twice as far from the *Point* by which the Balance was suspended ; here, I conjecture, half the Weight with twice the Celerity was equal to twice the Weight with once the Celerity.

P. You are very right : This is a good Example to give you a familiar Notion of the Center of Gravity of two Bodies.

M. But what do you mean by the Center of Gravity of more Bodies ? For you mentioned that also.

P. In your Example you know if the two Bodies be suspended by their common Center of Gravity, neither of them will over-balance the other, more than if they were both placed in that Point.

M. Neither of them will.

P. Suppose then the *Beam* long enough, and a *third Body* (equal, for Instance, to a tenth Part of the Weight of both these Bodies taken together,) placed on the Beam at a Distance from them.

M. What then ?

P. Then the Center of Gravity between this *third Body* and the *former two*, considered now as one Body, will be ten times more distant

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distant from *it*, than from their Center of Gravity: So that if the Beam were now suspended by this Point, this *third Body* would be a counter-poise for both the former Bodies.

M. Then you suppose the *two former Bodies* to weigh exactly as if they were placed in their common Center of Gravity, in Order to find out the Center of Gravity between them and this third Body?

P. Exactly the same Way.

M. And *this Point* last found will be the common Center of Gravity of all three?

P. It will.

M. And if I were to find out the Center of Gravity between *these three* and a *fourth*, I should suppose all three suspended, or placed at their common Center of Gravity, and proceed as before; that is, as if there were but two Bodies?

P. You have it.

M. This is both easy and pleasant. Pray let me mention a Particular I have often observed, which I think has some Relation to this.

P. I shall be glad to hear it.

M. When I have struck against any Thing with a Stick, if the Stroke was too
near

near my Hand, or too near the End of the Stick, my Hand was strongly shaken some how, and I felt Pain from the Stroke ; but otherwise it was easy and not painful to me.

P. In this Case, *Matbo*, there is a Point in the Stick, or in any Thing with which you strike, called the *Center of Percussion*. When the Stroke falls on *that Point*, it is smooth and easy to the Hand ; for the Parts of the Stick on each Side balance each other, and the Thing against which you strike receives the whole Force of the Blow. But if the Stroke falls too near your Hand on this Side, or too near the End of the Stick on the other, your Hand bears a Part of the Force, and is severely shaken by it, which occasions Pain.

M. And whereabouts in the Stick may this Point, or *Center of Percussion* lye ?

P. About two thirds of the Length of the Stick from your Hand ; or one third of it from the other End.

M. Then this gives me some Idea of the *Center of Percussion*. —

XCVI. But to return ; Why do you suppose that the Earth and Moon should

revolve about their common Center of Gravity, rather than that the Moon should revolve about the Center of the Earth, which revolves about no Center but the Sun, the common Center of the Motion of all the primary Planets?

P. The Earth and Moon, you know, mutually attract each other; and if we suppose no other Action to intervene, which may hinder the Earth to yield to the Moon's Attraction, it is impossible the Moon should revolve about the Earth at Rest, without its being brought still nearer and nearer to the Moon, 'till at length they come close together.

M. I own I do not conceive this at all.

P. Imagine the Moon to roll about the Earth at rest, (no other Action intervening) and in that Case the mutual Attraction between them cannot bring the Moon nearer the Earth, because she has a centrifugal Force by her circular Motion, which hinders her from yielding to the Earth's Attraction: But the Earth having no such centrifugal Force, as being supposed at Rest, must yield to her attractive Power by little and little, 'till at length they meet each other.

M. Thus

M. Thus far I see: Their Attraction would grow stronger and stronger, as they drew nearer, till at last they rushed towards each other.

P. That would be the Consequence: But if, to prevent that, the Earth should have a projectile Force impressed upon it, in a contrary Direction to the Moon's, and with a proper Celerity (*i. e.* so that its Celerity might be a fortieth Part of the Moon's,) then it will have an equal centrifugal Tendency, and their mutual Attraction will as little prevail upon it, as upon the Moon.

M. The Matter now is intelligible: If two unequal Bodies were tied together by a Rope or Cord, and a Force only impressed on one of them (the greater suppose) *That* would drag the other after it: But if a Force were impressed on both, side-wise to the Tension of the String, and in contrary Directions, so that the Velocity of the less were as much more than that of the greater, as the Quantity of Matter in it were less; they must both necessarily revolve about such a Point as made their centrifugal Forces equal; that is, about their common Center of Gravity.

P. You

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P. You enter very naturally into the Thought.

M. Since the greater Body must always be nearer the common Center of Gravity. This brings to my Mind *Tycho Brabe's* System of the Planets, where the Earth was supposed in the Center, with the Sun rolling about it: Which was like supposing a Mill-Stone rolling about a Pebble.

P. I am glad you remember so well that this obvious Reason easily shews the Absurdity of that ingenious Fiction.

M. But in the present Case, Why do you make such an Exception, *If no other Action intervene?*

P. Because a stronger Action than their mutual Gravitation might hinder the Earth from moving thus about their common Center of Gravity, and then the Moon must revolve about the Earth as the Center of her Motion.

XCVII. M. I conceive it: But then, how do you shew that, if both of them revolve about the Earth as their common Center of Gravity, the *primary Planet* must constantly receive a Variation of Impulse

pulse in a different Direction, as well as the Satellite?

P. You know then both of them revolve about a Point (their common Center of Gravity) which revolves about another Point, (the Center of the Sun :) In this Case therefore it is the Center of Gravity that describes a circular Orbit about the Sun, and neither the Earth nor the Moon, which revolve immediately about it. — Now, tho' their Center of Gravity were at Rest, both the Earth and Moon must receive a projectile Impulse in contrary Directions, and with different Velocities, (as forty and one, to wit,) about this Point; just as it was in your Example of the two Bodies tied together with the Rope or String: For if one of them only received an Impulse about *it*, and the other not; that other, wanting centrifugal Force to resist their mutual Attraction, would be drawn nearer the Body which had centrifugal Force.

M. I perceive it must be so.

P. This would be the Case if their common Center of Gravity were at rest, and the Sun absent. But that *this Point*, about which they roll, may be carried in a cir-
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cular Orbit round the Sun, both of them must also receive an Impression, always parallel to the circular Motion of *this Point*; just as the Moon, in the former Supposition, was to receive an Impression always parallel to the circular Motion of the Earth.

M. I begin to penetrate a little into the Matter.

P. I say the Earth now, as well as the Moon, must receive an Impression always parallel to the circular Motion of *this Point*: For if in the former Case the Earth's Attraction was not enough to carry the Moon along with itself round the Sun, without such an Impression; the Effect of that Attraction being but about 16 Feet in a Minute; so in this Case the Moon's Attraction would be less able to carry the Earth along, were not an Impression made on it likewise; the Effect of her Force being but a 40th Part of 16 Feet in a Minute.

M. It is plain the Earth must receive an Impression as well as the Moon.

P. Then the Direction of this Impression must always be changed, and the Impression itself therefore renewed, because the Direction of the *moving Point*, to which

it must still be parallel, is always changed; since it describes a circular Orbit round the Sun. For as, in the former Case, the Impression made on the Moon was still to be parallel to the Earth's circular Motion, and therefore still to be renewed; so in this Case, the Impression made on the Earth is still to be parallel to the circular Motion of their *Center of Gravity*; and therefore still to be renewed.

M. You have now gone through the whole Argument, *Philon*, Step by Step, so clearly, that I perceive the Necessity of the Reasons all along; and it is as you said. This makes the *projectile Force* of the primary Planets, which otherwise would be owing to one original Impulse given them at the Beginning of their Rotation round the Sun, as much to require a constant Variation of Impression, as that of the Secondaries themselves. You raised my Admiration before, when in our preceding Conferences you shewed me by what wonderful Means a primary Planet revolves about the Sun; But now when I consider what constant Attention, and manifold Impressions it requires, to make a *secondary Planet* revolve about a *Center*, which itself must revolve about

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about *another Center*; Words lend but a feeble Aid to represent my Astonishment. A simple circular Motion requires a constant Change of Direction, and therefore a constantly renewed Impulse: But when one circular Motion is blended with another, and both are wrought into one (if I may so say) in the same Body, without Disorder or Confusion; and when this amazing Composition is multiplied with the Number of Satellites in the same System; the Heart of Man cannot sufficiently admire the Wisdom of the *Creator* in contriving, nor his Power and Goodness in the constant Execution of such a wonderful Work!

P. Hence, *Matbo*, it appears more and more evident, how little Satisfaction there is in Philosophy, if we exclude the immediate Action of the Deity. The Knowledge of the Laws of Nature is only the Knowledge of the Laws by which the *Creator* acts in preserving the Universe. We attempt an impossible Thing when we endeavour to explain these Motions without his immediate Action. And even *They* pass over the Consideration of many Particulars, who acknowledge the immediate Hand of the *Almighty* in constantly renewing the centripetal

centripetal Impulse ; but imagine that the projectile Force once impressed on the Planets hath remained unvaried since the Creation of the World, without the farther Interposition of the Deity.

XCVIII. *M.* I think I now understand something more of the compound Motion of the secondary Planets than formerly I did ; or at least I see how difficult such a Motion is to be understood : And likewise from what you said in the Beginning of our Discourse, I fancy I can guess at the Reason why the Action of the Sun, tho' predominant over the whole planetary System, does not disturb, or confuse, the Motion of the secondary Planets, in these lesser Systems of *Saturn*, *Jupiter*, and our *Earth*.

P. What is the Reason you would assign, why this does not happen ?

M. You observed then, from what we had said before, That the Attraction of the *great Bodies* in our System does not immediately cease at their Surfaces, but prevails through a certain spherical Space round them, according to the Quantity of Matter each of them contains ; which occasions

fions the *relative downward and upward* we have so often spoke of, peculiar to every great Body in the System. Hence I suppose, if a Body were placed in any of these particular Spheres, it would fall to that Planet within whose Attraction it were thus placed, and not to the Sun, or any other Planet. And on this account the Action of the Sun does not separate the Bodies in any of the lesser Systems; because the Satellites are within the prevalent Attraction of the Primary Planets about which they roll.

P. You go on here at a great rate, *Matbo*, without any Assistance.

M. The Subject appears natural and easy, from what we have said before.

P. But how could you satisfy another Person, that the Force, whereby a Satellite is retained in its Orbit about the Primary Planet, points to that Planet?

M. The same way that I could satisfy him that the Force, whereby the Primary Planets themselves are retained in their Orbits about the Sun, points to the Center of the Sun. I see plainly an Impossibility that any Body should move in a circular Orbit about a Center in a free Space, unless it were constantly urged by a Force pointing to that Center,

Center, compounded with a projectile Tendency, or a Tendency to recede from that Center in every point of its orbit. This must hold as much with respect to one Center as another ; as much with respect to the Centers of the Primary Planets about which their Satellites revolve, as with respect to the Center of the Sun about which the Primary Planets revolve. You alledged indeed, as a Proof of this, that where there are more Satellites than one in the same System, the Squares of their periodical Times round the Primary, and the Cubes of their Distances from it, are in the same Proportion ; which is the Law that obtains with respect to the Motions of the Primary Planets themselves about the Sun : But whatever Strength there may be in that Argument, it depends on you to make me understand it. Though even without that, the Case seems to be plain to Reason and common Sense. For tell me, does not the *centrifugal Force*, arising from the circular Motion, balance the *centripetal*?

P. Certainly.

M. If then the circular Motion were stopt, or if the Satellite had no centrifugal Force, what would be the Effect of the *centripetal*? Would it not draw down the Satellite to the

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Center

Center of the *Primary*? Or in respect of
what Center is it a centripetal Force?

P. You prove this Matter convincingly enough.

M. And on this Principle it is, I suppose, that you said before, the Moon would be drawn down in a Minute some more than sixteen Feet, towards the Center of the Earth?

P. It is: And on the same Principle too Mathematicians shew, in what Time any of the Satellites would fall to the Center of its Primary; or in what Time the Primary would fall to the Center of the Sun.

M. There must be something therefore under this Question, since it is so plain; otherwise you had not made a Question of it; and I must endeavour to be upon my guard.

P. Tell me next, How are these particular Spheres of Attraction of the Planets separated from the general Attraction of the Sun, which obtains over the whole Planetary System?

M. As the Attraction of any Planet (our Earth, for Instance) draws a Body towards its Center, and the Attraction of the Sun draws a Body towards his Center; there must

be a *Limit* betwixt them, where the contrary Attractions are equal, and where, if a Body were placed, it should have a Tendency to neither. From the Earth on the one Side, or the Sun on the other, to this Limit is *upward*: And contrarily, from this Limit to either is *downward*. Gravity therefore (as you observ'd) is but relative, and no way essential to Matter; since a Body placed at this Limit would gravitate to neither Center.

P. You are certainly in the right, *Mathe*: For as the Earth attracts a Body at its Surface more strongly than the Sun attracts it; and as the Sun attracts a Body at his Surface more strongly than the Earth does; and since the Force of both Attractions decreases in a certain Proportion, as the Distance from the Sun or Earth increases; it must be, that in some certain Point between them their attractive Forces should be equal.

M. This is what I meant: And therefore if a Satellite keeps within this Limit, it must revolve about its Primary, within the Sphere of whose Attraction it is. Hence likewise I suppose, the greater the Sun's Distance is from the Earth, or any other Primary Planet; that is, the larger the Solar System is supposed to be; the larger the Sphere of Attraction of

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the Earth, or any other Planet, must be of consequence; or, the farther *this Limit* between the Sun and it will be removed from any other Body in the System.

XCIX. *P.* It is very natural, *Matho*, for you to imagine so; but in Reality the thing is directly contrary to what you suppose.

M. Pray shew me my Mistake in this Particular.

P. I must first tell you that the Force of Attraction decreases in receding from the Center of the Sun (or of any other attracting Body) as the Squares of the Distances from that Center increase; and contrarily.

M. Explain this by an Example.

P. The Sun at twice the Distance attracts a Body but with a fourth Part of the Force, it would do at once the Distance; and at thrice the Distance, but with a ninth Part of the Force.

M. I understand; and at four times the Distance, but with a sixteenth Part of the Force: And so on.

P. It is so: And when the Distance is lessened; at half the Distance he attracts four times more strongly, at a third Part the Distance, nine times more strongly, &c.

M. This

M. This is a Consequence of the last Case.

P. Since then the Attraction decreases, as the Squares of the Distances increase; and increases as the Squares of the Distances decrease; both Cases are thus briefly expressed. *The attractive Force is inversely as the Squares of the Distances from the attracting Body.*

M. This is short indeed, and plain too, when one considers the Examples. —

P. Thus the Attraction decreases, as the Distance of the Sun from the Earth is increased. Let us consider next how it will be increased, notwithstanding the Sun always appears of the same Magnitude whatever his Distance be: For as the Attraction grows less in the one Respect, it grows greater in the other.

M. Pray shew me how that is.

P. If the Sun were at twice the Distance, his Diameter must be twice as big, that it may appear but equally large to us: As a *Pole*, or *Tree*, that it may appear to the Eye at twice the Distance as high as another at once the Distance, must in reality be twice as long.

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M. It

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M. It must be so according to common Sense, and by an easy Proposition in the *Elements of Euclid*.

P. Therefore at twice the Distance the Sun's *Disk*, or Surface, must in reality be four times as large, as at once the Distance, that he may appear to the Eye but equally big.

M. This I think I likewise understand: For a Square whose Side is two Feet, is four times as large as another whose Side is but one Foot.

P. Right. Hence the Sun at twice the Distance must have eight times the Quantity of Matter in him, to appear equally large to our Eye, he would need at but once the Distance: For a Cube whose Side is two Feet, or a Sphere whose Diameter is two Feet, is eight times as big as another whose Side, or Diameter, is but one Foot.

M. It is so indeed.

P. And by the same sort of reasoning, going on with the Steps accurately, you will find that the Sun at thrice the Distance must have twenty-seven times the Quantity of Matter in him, to appear of an equal Diameter to the Eye, that he would require at once the Distance. And at four times the Distance,

Distance, he must have sixty-four times the Quantity of Matter in him; And so on.

M. I see already that these are but Repetitions of the first Argument, on the Supposition of different Distances of the Sun.

P. That is to say then, the Quantity of Matter in the Sun must be as the Cubes of the Distances we suppose him to be at from us.

M. Because his Diameter is increased with his Distance; and his Matter with the Cubes of his Diameter?

P. Right.

M. What do you infer from all this?

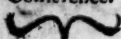
P. At twice the Distance the Sun will attract four times less upon the account of his double Distance; but then he will attract eight times more upon the account of his octuple Matter: That is, in effect, he will attract twice as strongly as at once the Distance.

M. You will leave me behind, if you go on so fast with your Argument.

P. Take it thus then. An equal Sun at twice the Distance would attract but with a fourth part of the Strength of our Sun at half the Distance, being twice as remote from us: But that he may appear of an equal

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Bigness.



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Bigness to us with our Sun, he must have eight times the Quantity of Matter in him; and on that account must attract eight times more than this fourth Part: That is, he will attract twice as forcibly as at once the Distance.

M. I understand it now: His Distance lessens his Attraction, but his Quantity of Matter (growing faster than his Distance) increases it more than it is lessened.

P. It is so: And by the same Argument repeated, you will perceive that, at thrice the Distance he will attract thrice as strongly; and at four times the Distance four times as strongly as when we suppose him at once the Distance.

M. It will indeed follow.

P. All this is thus comprised in few Words. Since the Attraction of the Sun decreases inversely as the Squares of his Distance, but increases directly as the Cubes of his Distance; absolutely speaking it will be increased as his Distance directly. Thus if his Distance be 20000 Semi-diameters of the Earth from us, he will attract the Earth twice as forcibly as if it were but 10000 Semi-diameters: and if it be 30000 Semi-diameters, thrice as forcibly: And so on.

C. M. You

C. M. You have given me a good deal of Light into this matter, in a short Time : And from this I see; the Attraction of the Earth remaining still the same, whatever the Sun's Distance be ; the farther we suppose the Sun removed from the Earth, the nearer this *Limit of equal Attraction* will approach to the Earth ; and the less we suppose his Distance from us, the farther *that Limit* will recede from it : The contrary of which I should have inferred, had I been left to my self.

P. You may likewise be satisfied of this from another Consideration : For the greater the Sun's Distance from the Earth is, the larger its annual Orbit must be, as having a larger Radius ; and the larger the Circle is, which is run over by the Earth in the same Time, the greater the Earth's centrifugal Force must be : The centrifugal Force in this Case increasing directly with the Radius, or Distance of the revolving Body.

M. I see it plainly : And the greater the Earth's centrifugal Force is, the stronger the Sun's Attraction upon it must be, to keep it from flying off ; and the stronger the Sun's attractive Force is, the nearer the Point, where

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where the Earth's Force and his would balance each other, must approach to the Earth. So that I am satisfied now upon a double account that this is so. But pray might not *this Limit* be determined, according to any particular Distance the Sun were supposed to be at from the Earth?

P. It might with no great Difficulty.

M. Then I think it would be very agreeable to assign that *Boundary*, beyond which our Moon could not roll. We should thus see, upon the Supposition of any particular Distance, how nearly she were hemmed in; or if there were room for another Satellite to revolve without her. I should even think that assigning this Boundary might be of use to help to determine the Sun's real Distance from us; in case, on the common Supposition, *it* were found to be so near the Moon's Orbit, that the Sun could not be farther removed from us, without *this Limit's* encroaching on the Space in which the Moon were to revolve.

P. Here we must proceed by degrees, *Matho*; for though what we have hitherto said seems plain to you and me, yet it will not be easily allowed that the Moon's Motion would be disturbed, though the *Limit* of

of *equal Attraction* between the Sun and Earth fell within her Orbit.

M. Would the Moon revolve as a Satellite about the Earth, if she were more attracted by the Sun than by the Earth in the interior part of her Orbit?

P. This Particular of disturbing the Motion of the Moon is explained in a different manner. There is an *Axiom*, or *Proposition* in Philosophy, which shews, we are told, that the Moon's Course might be preserved regular about the Earth, tho' she were a thousand times more attracted towards the Sun than to the Earth*.

M. A thousand times! Pray what is the Proposition?

P. It is this; *If Forces in parallel Directions act equally on all the Bodies of any System, their relative Motions cannot thereby be disturbed.*

M. I remember you mentioned something like this Axiom before, when you shewed me the Difference between *absolute* and *relative Motion*; and then I thought I saw in what Sense it was true: But as it is applied

* See the History of the Works of the Learned, for October 1738. Art. XXX, Pag. 269.

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here I do not see the Force of it, and think it is strained too far.

P. How did you understand it then?

M. I suppose the Axiom was to be so understood, that the *Parallel Forces* impressed on the several Bodies of the System were not to destroy the particular Forces, whereby those Bodies moved relatively among themselves: Or, that all the Bodies of the System yielded equally to, and were equally carried along (in the immense Space suppose) by the parallel Forces. And on these Conditions the Sense of the Axiom seems plain and obvious: But in the present Case, where the *Earth* and *Moon* revolve about the Sun as a Center, the Circumstances are very different; therefore the Axiom seems less applicable. The Sun in the Conjunction of the Moon attracts her one way, and the Earth (which doth not yield to the Sun's Force, so as to draw nearer him) attracts her the other: And in this Case, if the Sun's Force in drawing the Moon down towards himself were a thousand times greater than the Earth's in drawing her the contrary way; or if the *first* were but barely equal to the *last*; then the Axiom, instead of shewing that the relative Motions of the System could not

not thereby be disturbed, seems to me to shew that the *System itself* should be quite dissolved.

CI. P. But here you leave out the principal Condition, which is, *That the Earth be equally attracted with the Moon.*

M. That Condition, as I take it, does not shew the Thing intended. For the Earth's centrifugal Force hinders it from drawing nearer the Sun, or being carried along with his Attraction, how great soever it may be supposed to be: But when the Moon descends to her Conjunction, her centrifugal Force in her own Orbit rather conspires with the superior Force of the Sun. And tho' we should suppose that the *Impression* we spoke of before (which is still made on the Moon parallel to the Earth's circular Motion) hindered her from descending to the Sun; yet it could never assist her in rising after her Conjunction through the opposite part of her Orbit; since this *Impression* would carry her in a concentric Circle to the Earth's Orbit, or bend her Course the contrary way. Of the *four Forces* therefore, which act constantly upon her, *three* resist her rising after the Conjunction; viz. the Sun's attractive Force, the

the Force impressed always parallel to the Earth's Motion, and her centrifugal Force in her own Orbit: Whence we have nothing left to make her mount towards the Earth's Orbit, but the weaker Attraction of the Earth itself. It is here I conceive where the Difficulty lies; and in turning up again it appears to me the prevalent Attraction of the Earth is necessary: Otherwise she would move from her Conjunction (not indeed down to the Sun) but forward in a separate Orbit of her own, incurvated to the Sun, and bent from the Earth, which must separate her from rolling about the Earth as a Satellite.——

P. Have you done?

M. I may not perhaps have spoke so intelligibly as I could wish; but what I mean in short is this. The Orbit of the Earth is every where equally distant from the Sun; therefore the Earth never yields to the Sun's Attraction: For as its Gravitation would carry it down to the Sun, and its projectile Force would carry it to a greater Distance from him; by a Composition of both Forces it keeps still at an equal Distance from him. But the Moon sometimes descends nearer the Sun, and after that ascends to a greater Distance

stance from him: And this rising to a greater Distance is not relative but absolute. For when the Distance between two Bodies is changed, one of the two at least must have a *real* and *absolute Motion*; and it will not be said, I believe, that this *real Motion* belongs to the Sun. Now when the Moon moves absolutely to a greater Distance from the Sun, it must be by moving against the whole Force of his stronger Attraction, by means of the weaker Force of the Earth; which appears to me really impossible. And if this be so, it must be a false Explication of the Axiom, which makes it contradict a plain and self-evident Truth, *viz. When two unequal Forces are at once impressed on the same Body in contrary Directions, it must yield to the stronger, and not to the weaker.*

P. I both understand what you said before, and what you say now, very well; nor do I see at present what can be reply'd.

M. It appears to me likewise, that we may come to the Solution of this Difficulty very easily thus. Imagine the Earth to stand still in the same point of its Orbit, hindered by some Power or other from yielding to the attractive Force of the Sun, while the Moon performed her menstrual Course

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Course about it: And if the Attraction of the Sun were stronger than that of the Earth, she must yield to that prevalent Force, and be carried off from the Earth. Now when the Earth has its projectile Force impressed upon it, no new Force is impressed upon the Moon, except that in a parallel Direction always to the Orbit of the Earth: And *this*, as has been observed, could never help to carry her upward from the Conjunction; but would rather bend her Course concentrical to the Earth's.

CII. *P.* Your Reasoning becomes clear and intelligible, *Matbo*, by arguing thus from the Point of the Moon's Conjunction: But if the Limit of equal Attraction between the Earth and Sun lay within the Moon's Orbit, it seems no less true, that she would be drawn out of her Course from any Point in the interior half of her Orbit.

M. Pray make me understand how this could be.

P. If this Limit were at the Distance of 40 Semi-diameters of the Earth (*ex gr.*) from its Center, that is, 20 Semi-diameters within the Orbit of the Moon; imagine a Semi-circle concentrical to the interior half of her

her Orbit, described through this Point. And since the Attraction of the Sun is nearly as great at the Earth's Orbit, as at the Point of the Moon's Conjunction, this Semi-circle will shew every where the Limit of equal Attraction between the Sun and Earth; and therefore it shews that the Moon is within the stronger Attraction of the Sun through the whole interior half of her Orbit.

M. It is very plain. I conceived the Limit of equal Attraction confined to one Point; namely, in a Line reaching from the Center of the Earth to the Center of the Sun: But this Semi-circle shews me the whole Bounds of the Sphere of the Earth's Attraction, with respect to the Sun. For if the Semi-circle were turned round on its Radius which passes through the Center of the Earth, it would form an Hemisphere circumscribing the Earth's Attraction, and dividing it from the Sun's superior Force.

P. This seems to me a natural Conception of the Case.

M. If then we have reasoned rightly hitherto, this Condition, I think, ought to be added to the *Axiom* above; *viz.* Not only that the parallel Forces act equally on all the Bodies of the System; but that the whole

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System yield to these Forces, or be equally carried along by them. Otherwise we shall so explain *this Proposition*, as to make it contradict the self-evident Truth I mentioned just now.

P. These are the Conditions on which you said the Sense of the Axiom was plain and obvious. Now it would much conduce to the clearing up of this whole Affair, if you could shew by plain Examples that the Axiom holds on these Conditions, and cannot hold without them.

M. Let me take a little Time to digest my Conceptions.

P. Take your own Time. —

M. Let us first suppose that two Bodies were carried along in a free space, with equal Celerity, and in the same Direction, by the parallel Forces. They would then be relatively at rest, or they would not change Distance with respect to each other: And in this case it is easy to see that a small Force might make them approach to, or recede from one another. Let them be ten Feet asunder, and carried down at the rate of ten Feet in a Minute; and let the *last*, or *greatest* of the two, attract that which is before it, at the rate of one Foot in a Minute.

I choose

I choose these small Numbers and Quantities, that the Imagination may not be perplexed with Distances and Forces almost incomprehensible.

P. You do right to make the Supposition as simple as possible: That is the readiest way to come at the Truth.

M. In these Circumstances the *two Bodies* would come together in ten Minutes, after the *uppermost* or *last* had moved an hundred Feet, and the *undermost* ninety: For here in every Minute the Motion of the *under Body* is retarded one Foot by the Attraction of the *upper*; and in effect it is the *upper Body* which approaches the *lower*, or runs over the whole relative Distance between them: Or it is the *upper Body* that descends with the parallel Force in this case, and not the *under Body* that mounts against it. That I take to be an absolute Impossibility. But now if we should suppose the *upper Body* to be detained in any manner, or hindered from being carried along by this parallel Impression, while the *lesser* and *lower Body* were left to follow its Impulse; this last would then be carried down from the other at the rate of nine Feet in a Minute; which is the Difference between the Effects of the two Forces.

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P. All this is undeniable.

M. Let us farther suppose while the *upper Body* remains fixed and immoveable, that the *under Body*, ten Feet distant from it, receives a tangential Impulse, in such Proportion as would make it revolve about the other in a Circle, if the parallel Forces did not act; and it is equally undeniable that this Body could not rise against the parallel Force, which is ten Times stronger than *that* wherewith it is attracted to a Center. For the whole Force of the Attraction is not opposed to this ten-fold greater Force, but in one Point.

P. If *one Degree* of Force overcome *ten*, certainly nine of them must be overcome by nothing.

M. Lastly, If we should now suppose the *upper Body* not fixed, but moving along by the parallel Impression, the *under Body* receiving the tangential Impulse, as before, would then revolve about it; not by rising absolutely against a greater Force, but by the other Body's falling down, and its getting relatively to the upper Side.

P. It appears to me, *Matho*, you have pursued your Supposition fairly enough, and shewn what you undertook.

CIII. M. It

CIII. *M.* It shews, if I have represented Things right, that when both the Bodies are carried equally along by the parallel Forces, their relative Motions are not thereby disturbed; but that without this Condition the System itself is dissolved. For where the *upper Body* was supposed not to be carried along, the *under Body* was carried off from it: Nor could *this last* revolve about it then in a Circle, though impelled by a projectile Force. And this is applicable to the Moon, if the Limit of equal Attraction between the Sun and Earth fell within her Orbit. She would be carried off by the stronger Force of the Sun in every Conjunction: Unless indeed we should have Recourse to the *Interposition of the Deity* to prevent this. Which, if it could be shewn necessary I should not be against: But for one to have Recourse to such Interposition here, though it were necessary, would be to give up the Axiom.

P. More, I think, needs not be said on this Head.

M. We may vary the Conditions of the Supposition a little, till we come to the Circumstances, in which only the Moon, as I

conceive, could revolve about the Earth.

— Thus, while the parallel Forces carry along the two Bodies at the Rate of ten Feet in a Minute, we may suppose that the *upper Body* attracts the *lower* just so much in that Time: In which Case the *lower Body* would move neither Way, but remain absolutely at Rest; and the *upper* would run over the whole Distance between them. If here the *lower Body* received a projectile Impulse in due Proportion, it would revolve about the *other*, not by rising absolutely against an equal Force; but by the *upper Body's* being carried down, and coming in below it. But if we should suppose the *upper Body* fixed, so as not to yield to the parallel Force, the *other* without a tangential Impulse would remain suspended between equal Forces, at the Distance of ten Feet still from the *greater*: And if this *lesser Body* received a tangential Impulse, it would then be thrown off at a Side from the *greater*; but could not revolve about it. And this would be the Case between the Earth and Moon, if the Limit of equal Attraction fell upon the Moon's Orbit; or if she were equally attracted

tracted by the Earth on the one Side, and the Sun on the other.

P. I have nothing to reply; every Thing seems as plain here as in the former Case. —

M. We may in the last Place suppose that the parallel Forces impelled the two Bodies at the Rate of but one Foot in a Minute, while the *upper Body* attracted the *lower* at the Rate of nine Feet in that Time. And in these Circumstances the *upper Body* would only move one Foot by the Force of the parallel Impression, while the *lesser* moved nine Feet against it: But here it moves by the stronger Force, and the whole System yields to the parallel Impression a Foot in a Minute. And though now the Descent of the *greater Body* were impeded, the *under Body* by this stronger Attraction would nevertheless come up to it. If then *this last* received a projectile Impulse, to give it a centrifugal Tendency, it would revolve about the *other* as a central Body, being within the Sphere of its more powerful Attraction, and having no where in its Revolution a superior Force to overcome. — Nay, though now both Bodies should receive an Impulse always in parallel Direc-

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tions, and at right Angles to the first parallel Forces; or tho' the first parallel Forces now tended to a distant Center, so that *this System* revolved about that distant Center; the *lesser* of the two Bodies would still perform its Revolutions about the *greater*; all these different Impressions being still regularly maintained by some *powerful* and *mighty Hand*. Which is exactly the Case of the Moon, more powerfully attracted by the Earth than by the Sun; or when the Limit of their equal Attraction falls without her Orbit.

P. To use your own Words, *Matbo*, the same Things are so often to be named, and the Conditions so often to be repeated, that there is some Difficulty in following the different Steps of your several Suppositions: But when they are distinctly conceived, the Reasoning seems very close. From the *first Supposition* it appears that the Moon could not revolve about the Earth, if the Limit of equal Attraction between it and the Sun fell within her Orbit; and the *second* shews that it would not be enough to make her revolve, though that Limit coincided with her Orbit. Whence it must fall without the Space she revolves in, according to the
Condi-

Conditions of the third Supposition. But it is certainly Time now to leave this Subject, since we have nothing more to say about it.

M. Permit me first to ask you a few Questions.——

CIV. Pray tell me, does any of the Distances assigned to the Sun bring *this Limit* of equal Attraction between the Earth and him, within the Orbit of the Moon?

P. If the Sun's Distance from us were 34000 Semi-diameters of the Earth, as some have supposed; that *Limit* would fall, at a middle Rate, 26, and sometimes 29, Semi-diameters of the Earth, within the Moon's Orbit; that is, about 104000, or 116000 Miles nearer the Earth than the Moon.

M. Then that Distance must certainly be too great; for it is inconceivable that such a large Portion of the Moon's Orbit should lie within the Regions of the Sun's stronger Attraction.

P. The whole interior Half of her Orbit, *Matho*, would then lie a great Way within his stronger Attraction; as has already

ready been observed: In which Case, the Earth's Force on the Moon would sometimes be little more than a fourth Part of the Sun's Force upon her. And here it is very remarkable, that the weaker the Earth's Force were on the Moon in Comparison of the Sun's, the more equal the Sun's Force would be on both the Earth and Moon, and the Directions, in which it acted on both, more nearly parallel: So that the Conditions required, according to the aforefaid Explication of the Axiom, for disturbing the Moon's Motion least, (*viz.* That the Sun attract both the Earth and her equally, and in parallel Directions,) would be attended with another Condition, which would dissolve it quite; namely, a great Excess of the Sun's Force above the Earth's upon her. And these inconsistent Conditions must always increase together.

M. Let me consider this a little, —
The greater the Sun's Distance from us is, the more equal his Force upon the Earth and Moon will be; because the Difference between the Squares of the Distances of the Earth and Moon from him must be the less. And likewise the greater his Distance is, he must attract both the more nearly in parallel

parallel Directions. But the greater his Distance is, the nearer the Limit of equal Attraction betwixt him and the Earth must approach to the Earth; or, the less the Earth's Force on the Moon must be in Respect of his. — I see it very plainly, *Philon*; it is as you say. *These inconsistent Conditions* must increase together. And this Consideration seems to make the Explication of the Axiom somewhat irreconcilable to itself: For surely it could not be pretended that the Motion of the Moon would be more irregular, if she were more attracted by the Earth than by the Sun; and yet the greater the Earth's Attraction were upon her, the less equal should the Sun's Action be on both her and the Earth. — Pray inform me next, if the *Limit of equal Attraction* between the Sun and *Jupiter*, or between the Sun and *Saturn*, fell within the Orbits of their Satellites; could that remarkable Proportion be then observed between the Cubes of the Distances and the Squares of the periodical Times of those Satellites?

P. It could not; for that Proportion is a necessary Consequence of those Satellites being attracted to the Centers of their respective

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spective Primaries, by the same Law as the Primaries are attracted to the Center of the Sun: That is, that their Gravitation to their Primaries be increased, as the Squares of their Distances from these Primaries decrease. Which Law could not obtain, if they gravitated more to the Sun than to their primary Planets.

M. It seems then, what could not agree to the Systems of *Jupiter*, or *Saturn*, could as little agree to the System of the Earth and Moon. For, tell me, if 3 or 4 Moons revolved about our Earth, would not they observe the same Proportion between the Cubes of their Distances and Squares of their periodick Times.

P. They would observe the same Proportion; for they would gravitate the same Way to the Earth, as the Satellites of *Jupiter* or *Saturn* do to those Planets. And it is observable here, *Matho*, that the great *Author*, to whom we owe the Discovery, and whole Theory of Gravitation, makes the same Supposition of more Moons revolving about our Earth; and concludes they would all observe this Proportion, and therefore the fundamental Law of Gravitation, where the attracting Forces are reciprocally

proccally as the Squares of the Distances from the attracting Body *.

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M. But they could not observe that Proportion, nor this fundamental Law, if they were a thousand Times, or twice, or but more attracted to the Sun, than to the Earth?

P. They could not then so much as revolve about the Earth, if we have reasoned rightly on this Point before. —

M. Absolutely speaking, according to this Sense of the *Axiom*, it is possible that the Moon might revolve about the Earth, though the Limit of equal Attraction between the Sun and it approached to its very Surface?

P. That is too extravagant a Supposition, *Mathe*, and makes the Earth's Attraction of little or no Use at all to the Moon's revolving about it.

M. Yet it seems a genuine Consequence of what is asserted: For why should any

* Si Lunæ plures circum terram revolyerentur, perinde ac fit in Systemate Saturni vel Jovis: harum tempora periodica (per argumentum inductionis) observarent legem Planetarum à *Keplero* detectam, et propterea harum vires centripetæ forent reciproce ut quadrata distantiarum à centro terræ. *Philosoph. Nat. Princip. Math. Lib. 3. Schol. Prop. 4.*

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Regard be had to the Earth's Attraction, if the Moon might revolve about it, and yet gravitate a thousand Times more to the Sun? Or is it impossible that the Sun should attract at the Surface of the Earth, as strongly as the Earth itself?

P. It is possible more Ways than one: But in that Case all Bodies on the Surface of the Earth would be loose, or in Suspense between two equal and opposite Attractions, and could not therefore revolve with the Earth on its Axis: Their centrifugal Force would throw them off towards the Sun.

M. Might not the Moon revolve about the Earth at four or five Times the present Distance from it; provided the Sun attracted the Earth and her equally?

P. Pray when will you have done with your Questions?

M. Very soon: Answer this.

P. If the Sun were at such a Distance as to attract the Earth and Moon equally, in that Case the Limit of equal Attraction would draw nearer the Center of the Earth, or fall more than 200 of its Semi-diameters within the Orbit of the Moon, when so far removed.

M. These

M. These several Consequences ought, I think, to have been considered.—You said that the Moon, by her Gravitation to the Center of the Earth would fall 16 or 17 Feet towards it in a Minute?

P. So much she is attracted from the Direction of her projectile Force in that Time; as the same great *Author* has shewn.

M. And that on these Principles the Time of her falling quite down to the Earth is easily computed?

P. With no great Difficulty.

M. Now I have done with my Questions, and shall stick to the first Reason why the Action of the Sun over the whole System does not draw the Satellites from their primary Planets; at least till I see stronger Arguments against it.

P. The Condition you add is reasonable.

M. At the same Time though I think it should stumble every Body, and they must despair of ever understanding these Motions, if the Explication of any *Axiom* suspended the plain and self-evident Truth I mentioned before; or shewed that, when two unequal Forces act at once on the same Body
in

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in contrary Directions, it may yield to the weaker in Opposition to the stronger.

P. As long as that Truth lies in the Way, it will be the more difficult to assign any other Reason than we have done, why the *secondary Planets* are not carried off from their *Primaries* by the Action of the Sun.——

M. Do you want to be relieved, *Pbi- lon*?

P. Very much: You ask Question after Question without Mercy.

M. I am glad of this Confession: My Imagination is a little fatigued with these Niceties, and not strong enough to enter on a new Subject; though I have not half done with the Particulars I designed to ask. Therefore I shall be with you again very soon.

P. Then we must agree for the future how long we are to discourse, and not talk on at your Discretion.

M. We may think of that hereafter.

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Matho desires to know why the Secondary Planets might not have revolved separately about the Sun, as the immediate Center of their Motion? If the Distance of the Satellites from their Primaries had been greater or less, what must the Consequences have been? That there may be more Bodies in the Solar System than are discoverable by us. In what Proportion the centripetal Force is increased or diminished, as the Planet is nearer to, or more remote from the Sun. From what Causes the centrifugal Force becomes greater or less. It is shewn necessary, by bringing the centripetal and centrifugal Forces to an Equilibrium, that the Cubes of the Distances of the Planets from the Sun must be as the Squares of their Periodical Times. And contrarily, as this Proportion holds in fact, from thence it is shewn, that the centripetal, Fugal,

fugal, and therefore the centripetal Force, must be inverfely as the Squares of the Planets Distances from the Sun.

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CV. P. I FIND, *Matho*, you keep your Word punctually; wherefore let us now settle how long we are to discourse.

M. I have observed, *Philon*, when a Man is every now and then looking at his Watch, to see whether the Hour be near, or past, his Head is more set on what he is to do, than what he is doing: So pray let us begin without any such Condition.

P. You will have every thing your own way.

M. My third Difficulty, as you may remember, was, Why the Secondary Planets should not revolve directly about the Sun, rather than about other Planets, which revolve about him? For there is a Simplicity in all the Works of Nature, though still pregnant with Variety of Effects; so that there must be some weighty Reason for this extraordinary Complication, and compounding of circular Motions with circular Motions.

P. It is very true; this could not be done without Choice and Design. The Great Architect of Nature might have disposed those

those Bodies in other different manners; but possibly in none either more wonderful, or more useful. The Power and Knowledge displayed raises our Wonder, you find, to the greatest Height; the Mind sinks under the Variety; for stretching to get a full View, it is soon forced to slacken in the Attempt: And as to the Usefulness, it is surely the most extensive we could conceive.

M. I know from Experience how soon the Mind is forced to slacken; but have no Notion of the extensive Usefulness of this complex Machination, which is the main thing I want to be informed in.

P. You will discover this yourself as we go on: In the mean time it is easy to perceive thus much of the Design. The Sun, as was observed before, is the *Fountain of Heat and Light* to the whole System: Upon this account the Poets sometimes called him the *Eye of the World*; and for the same Reason you inferred, that he was to be a Body of exceeding Magnitude and Grandeur, in respect of the Planets that roll round him.

M. I do remember it.

P. Yet it was not possible that all the Parts of the System; as well the remotest, as those that lie nearest to him; should

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enjoy this Advantage of his Heat and Light equally.

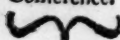
M. It was not: For as the Center of the System was the most proper Place for dispensing these with the greatest Equality, it necessarily follows that, while the Distance from the Center is increased, the Influence of his Rays must be less perceived.

P. Wherefore, though *Mercury*, which is next to the Sun, and perhaps *Venus* the second from him, sufficiently enjoy this kindly Influence from his direct Rays; yet our *Earth*, which lies at a greater Distance, hath a Moon to attend it: And it is by her throwing back on the Earth his reflected Splendor, that we enjoy the Light of the Sun more ways than one; and our Nights, especially in the Winter Season, borrow a secondary sort of Day from the Orb of the Moon.

M. I have often indeed admired the Difference of the Winter and Summer *full Moons*: When the Nights are long, the full Moon mounts high in the Heavens, and sheds a strong Light; but in the Summer Months she creeps dimly among the Clouds and Vapours near the Horizon: The Reason of which, I think, is not difficult to be found out.

P. It

P. It is rather necessary it should be so; but to proceed: As *Jupiter* is much farther removed from the *Focus* of the System (if we may so call the Sun) four Moons roll about him, which, by their quick Revolutions, variously illuminate the Hemisphere of that Planet turned from the Solar Rays, and pleasantly diversify his Nights, though otherwise remarkably short. For (if we might call the Revolutions of those Satellites by the Name of Months, as we do those of our Moon) some of the Months in *Jupiter* are not so long as two Days with us, consisting of but about forty-two Hours; others of them are less than four of our Days, and the longest of them, which contains forty of the Days in *Jupiter*, is hardly equal to seventeen Days with us. Whence some or other of these Moons must either be in the Opposition, and shine with full Lustre, or in the Conjunction, or in the Quadratures, almost every night. Besides, these Moons, by their manifold *Eclipses* (while they frequently dip into the Shadow of their *Primary*, often obscure the whole Body of the Sun, and sometimes intercept the Light of one another) afford a most entertaining Prospect, and instructive Phænomena to the



Inhabitants of that Planet, if any such there be.

M. This is really a noble, and (if I may so say) an expensive Contrivance for reflecting the Solar Rays on all the Parts of this large Planet: Though he does not enjoy so strong a Light as our Earth; yet I perceive he hath a far more delightful Variety of Splendor.

P. This Apparatus, *Matbo*, for reflecting the Light on all the Parts of the Primary Planet, is the more curious, if we consider that at great Distances from *Jupiter's* Equator the lower Moons cannot be seen; the Curvature of his Surface intercepting them from the Spectator's Eye: Therefore the other Moons are raised above these, to give Light (as it would appear) to those in greater Latitudes.

M. That seems really to be the Design.

CVI. P. The Contrivance is still heightened when we come to *Saturn*, the remotest of the Planets. He hath five Moons constantly rolling round him, which variously throw in the borrowed Light of the Sun on his distant Orb: And many suppose, because of the large Interval between the fourth and

fifth, that there is a *sixth* revolving there; though the Telescope has not yet been able to discover it. These, especially the four innermost, resemble *Jupiter's* Moons in the Smallness of their Distance from their Primary, and Quickness of their Revolutions about it: Therefore they diversify *Saturn's* Nights (which in all Probability are likewise but short) with various and beautiful Appearances of the same Nature as in *Jupiter*. But besides all this, he is surrounded with that sublime and stupendous *Arch*, which we mentioned elsewhere; and to which nothing is found equal, or like, in all Nature, so far as Mortals hitherto know. What a grand and noble Sight must it be, to behold in the Night time, such a lofty resplendent *Arch*, rising from the Horizon on each Side, and stretching up to the Heavens; which, as the Distance from it increases, seems the more august and stately! This prodigious *Annulus* itself probably turns round on its Axis; for it is reasonable to suppose that no Body in Nature, fitted for such a Motion, is without it. Thus the Shadow of the interior Planet, which always falls on one of the Sides of this Ring, when the Sun has a Declination to

either Tropick, must soon be removed, and the Light of the Sun restor'd.

M. Let me ask you, Does the Plane of this *Ring* fall in with *Saturn's* Equator?

P. It does.

M. Then I easily conceive that the Shadow of *Saturn* must be projected on that Side of it, towards which the Sun declines. Pray go on. These Appearances are new and singular, as if one were inventing something to amuse the Fancy.

P. It is not easy to reckon up the several different Appearances which this mighty vaulted Body must make to the different Parts of the Planet; or rather to a Spectator there residing. At some Times of *Saturn's* Year, and in certain Latitudes from his Equator, it eclipses the Sun every Noon, as he declines more or less to the opposite Side. And tho' the Duration of these Eclipses be still varying, yet they can never last long, if the diurnal Rotation of the Planet on its Axis be as quick as that of *Jupiter*.

M. Pray how far is the inner Edge of the Ring distant from the Body of *Saturn*?

P. About six or seven times the Semi-diameter of our Earth; and they reckon the Ring itself to be as broad.

M. Then

M. Then I conceive, methinks, since the Plane of the *Ring* falls in with *Saturn's* Equator, and since there is so large a Space open between it and the Body of the Planet, that in some Places where it is Winter, and the Sun declines to the opposite Tropick, he must appear under the *Ring* at Mid-day, shining through between it and the Body of the Planet : And contrarily, in Places more remote from the Equator, the upper Part of the Ring must eclipse him at Noon-day : And that these *meridian Splendors* and *Eclipses* must still extend farther towards either Pole, the farther the Sun declines to the opposite Side. For if the Arch of a Bridge lay South and North, the Light below and Shadow above must become shorter or longer, as the Sun rose higher in the Morning, or descended lower towards the West in the Evening.

P. This is indeed finely imagined!

M. Since these things are so, I am entirely for a diurnal Rotation of *Saturn* on his Axis ; otherwise these Eclipses would last, I presume, for some of our Years.— But pray what can the Design of this extraordinary Contrivance be ?

P. Alas!

MATHO: or, The

P. Alas! *Matho*, this is what I am not able to tell you. The greatest Men have hardly attempted this in Conjecture; and those, who have ventured to make Suppositions, have talked rather as if they had been thinking of the Ruins of some decayed Fa-brick, than the Works of an *Almighty Being*. From all Appearances it seems to be a Work still in Repair, and answering still the same Purpose for which it was originally contrived. Thus much only I think we may venture to say, That it was originally designed for some greater Purpose than barely to reflect the borrowed Light of the Sun on the Globe it furrounds: Since during one half of the Year in *Saturn* it intercepts as much Light, as it reflects the other. And certainly the Purpose it serves for, whatever that may be, cannot be less noble, than the Structure itself is strange and singular. —

M. How comes it then, *Philon*, that we should so ardently desire the Knowledge of Things which are without our Reach? Are those Desires unreasonable? or is the Accomplishment of them only impossible? If the Desires themselves are unreasonable, why should they be so strong? If they are not; why should it be impossible to gratify them?

P. You

P. You asked this before, as a *Question*,
Matbo; and now you urge it as an *Objection*.

In the Pursuit of Knowledge we should proceed by Degrees and with Attention: Every Thing in Time will appear consistent: We cannot discover the Reasons of Things by Precipitance and Impatience. We know not all the Wonders in our own Bodies, and therefore ought to be the less impatient, that we know not all Wonders in the Universe round us. You inferred perfectly well before, *That we can have no rational Desires, but what were designed to be gratified.* The Methods of Sense are not accommodated to the finishing our Enquiries, or the full Attainment of Knowledge. An Eternity of sensitive Life would be the greatest Misery to a rational Being, and could never have been proposed by the Author of the rational Nature. An Eternity of Sloth and Inactivity to an *active Nature* is no less absurd. We are so framed as necessarily to have interminable Views; but have not enough considered what would be the consistent Employment of interminable Existence to a rational and active Being. The Consideration of these Things would carry us a great way, and is foreign to our Purpose.

M. You

MATHO: or, The

M. You affect, I perceive, to talk mysteriously; and for all that I understand so much of what you say as gives me Pleasure: But, to leave a Subject you are unwilling to enter upon at present, tell me, —

CVII. If the remoter Planets had those Moons to attend them, in order to compensate their Distance from the Sun, by reflecting on them his borrowed Splendor; how comes it that *Mars* has none? He is more remote from the Sun than our Earth, which notwithstanding hath an Attendant to cast upon it this secondary light.

P. We cannot be certain that *Mars* is without a Satellite; the Learned are rather of Opinion that he hath one, though it be not conspicuous to the Inhabitants of our Globe, because of its Smallness: For as *Mars* is one of the least of the Primary Planets, it would be against the Order of Nature, if he carried along with him a larger Secondary. And it is the more probable that he is not unattended, because his Distance from the *Earth* is greater than the Distance of the *Earth* from *Venus*: And some reasonably suppose that even *Venus* too hath a Moon attending her. So that if there
be

be Room between the Earth and *Venus* for each to have a Satellite, without disturbing the one the other, there is still more Room between the Earth and *Mars* for this Purpose.

M. This Increase of Distance cannot indeed be for nothing; nor can we imagine that any of the Planets would have been set at greater Distances from the Heat and Light of the Sun, without a weighty Reason.

P. A Satellite of this Planet likewise must be more difficult to be observed, because the *Secondary* of a small *Primary* must revolve at a less Distance from it.

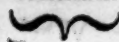
M. If then both *Mars* and *Venus* have Moons attending them, there will be *new Bodies* in our System.

P. Though as old as the System itself, they must be new to us; as *Saturn* and *Jupiter's* Moons were, which lay hid from the Eyes of Men, through all past Ages, and must have still remained unknown, had not the happy Invention of the Telescope discovered them, not very many Years ago.

M. At this rate we cannot be certain that we know all the Bodies of our own System.

P. Nothing that concerns the Welfare of the System depends on our Knowledge.

The



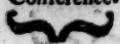
MATHO: or, The

The Ancients thought they knew all the Bodies of the System, when they reckoned but eight of seventeen which we know. Nevertheless concerning this Matter I would have you conceive thus. — The Solar System, with respect to us the Inhabitants of the Earth, consists of those Bodies which we can perceive: But if a Spectator were to be carried from one part of the System to another, he would lose Sight of some Bodies that were before conspicuous to him, and others he knew nothing of before would come in View. Thus were he placed in *Saturn*, he could perceive none of the inferior Planets, except *Jupiter*, which would appear to him so to move about the Sun, as *Mercury* appears to do to us; but at a somewhat greater Distance: *Jupiter's* greatest Elongation from the Sun appearing there to be about thirty-seven Degrees, and *Mercury's* here about twenty-eight. As to *Mars*, *Venus*, or our Earth, a Spectator placed in *Saturn* could never know that there were such Bodies in Nature, unless he chanced to espy them like dark Spots in the Disk of the Sun, while they passed in their retrograde Motion, between that Luminary and his Eye; as we sometimes perceive *Venus* and *Mercury*. And from

from this accidental View of such *black Points* in the midst of the Light, he could not in the least conjecture what they were; or that they were Planets carried by the same Laws about the Sun, as *Saturn* himself is. Yet he would have a *glorious Heaven* over his Head, illuminated with five bright Moons, (or six probably) besides the wonderful *pendulous Arch* we spoke of, and the innumerable Host of fixt Stars. The surprising Phenomena of those nearer Bodies would make him look upon *Saturn* as the most delightful Seat in Nature. Nay, when the Spectator had come down so far as *Jupiter*, he could even there perceive none of the four inferior Planets, unless by the same Accident as in *Saturn*, or the Help of better Inventions than have been hitherto discovered. If we suppose him assisted with such Helps, and that he had Skill to make Observations, he might still see the *Train* he left behind him, but not the noble Appearances they made in the *upper Planet*: But this could not be a Sight for common Eyes, or of daily Use.

M. It must be so: For, if we may compare small Things with great, the most stately Fabricks shrink into a diminutive and confused Appearance, when we are removed

but



MATHO: or, The

but a few Miles from them; and others we did not formerly attend to grow magnificent and stately as we draw near them.

P. That is the very Case here: *Jupiter* in the Approach would swell immensely to the Eye, so as to make the Grandeur of *Saturn* to be quite forgot; and besides the *Firmament of fixt Stars* and the superior Planet *Saturn*, the Spectator would here be entertained anights with four refulgent Moons, each appearing much larger than the Sun himself; whose different *Phases*, nimble *Revolutions*, and various, as well as frequent *Eclipses*, would continually afford him rational Amusement.

CVIII. M. Pray proceed; you carry me on delightfully through the several Parts of our Planetary World. Methinks I see the *Heaven of Jupiter*, or *Saturn*, much more beautiful than what we perceive here in a Winter Evening. These radiant Moons, in the Neighbourhood of their *Primaries*, must engage a Spectator there more strongly in the Contemplation of Celestial Appearances; and in my Opinion make him more easily acquainted with the Laws and Principles of these Motions, than can be done here with us.

P. I am

P. I am of the same Opinion: For having a compact System of Planets so near at Hand, and residing on a larger Body, whose Semi-diameter bears a great Proportion to the Distances of these neighbouring Moons, he would have great Advantages in making Observations, and consequently in discovering the fundamental Law of Bodies revolving about a Center, by the Composition of a centripetal and projectile Force. —But if we suppose the Spectator brought down to *Mars*, the Celestial Appearances will have quite changed their Face. He would indeed perceive our Earth going before, or following after the Sun, as a Morning or Evening Star, after the same Manner as we do *Venus*; though its Elongation from the Sun would not be quite so great; and *Venus* would appear to him, as *Mercury* does to us, generally obscured, to wit, by the Neighbourhood and brighter Rays of the Sun. But for *Mercury*, he could not get a Sight of that Planet, unless he espied him by Accident as a small black Speck on the Sun's Disk. And for the like Reason the learned *Gregory* supposes, that we the Inhabitants of the Earth cannot be certain, that there is not another primary

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Planet inferior to *Mercury* himself, or between him and the Sun. But the Spectator in *Mars* would see the two superior Planets, *Jupiter* and *Saturn*, though without their shining Moons. Whence the Nights in this Planet, which are nearly of the same Length as ours about the Equinoxes, must be more dull and languishing than our Nights about that Time, unless he be accompanied by a Moon of his own. And as a Spectator *there* could not perceive our Moon with less Difficulty than the celebrated *Cassini* got once or twice a Glimpse of *that* of *Venus*; so it must be still more difficult for a Spectator *here* to get a View of his Moon, as being less, and rolling at a less Distance from him. — Thus you see, *Matho*, that the same System must appear to consist of very different Bodies, when a Spectator is supposed to be carried up and down through the several Parts of it. It is no Argument therefore that Bodies which make for the Symmetry and Order of the System are wanting, because we do not perceive them: It is rather probable that there are several Planets, either primary or secondary, which the Industry of Mortals hath not yet discovered; nor perhaps ever will.

Who

Who before *Gallilæo* could have suspected that *Jupiter* had been so nobly attended? Or, who would have believed that *Saturn* was accompanied by such a Train of Moons, before *Cassini* and *Huygens*? It is reasonable to think that there are no *Chasms*, or unnecessary vacant Spaces in the Solar System. The disproportionately great Distance between the *fourth* and *fifth* of *Saturn's* Satellites, made the last mentioned great Man suspect, that a *sixth* Satellite revolved in that Space; or (which is more remarkable) that perhaps the uttermost Satellite had other Satellites revolving about it.

M. That would be more remarkable indeed, and, I think, past all Comprehension; if a Body revolved about another as its Center, and that other about a third as its Center, and that still about a fourth as its Center, who could conceive this Composition of circular Motions!

P. What is hardly to be conceived by us does not therefore become impossible to the Divine Power, if the Conveniency of the Work requires it.

M. That is certain. —

P. All these sixteen Bodies revolve about the Sun almost in the same Plane; in the

same Plane, namely, that which the Earth moves in : But there are *other*, and those *more numerous Bodies*, which traverse the System all Manner of Ways, and which are likewise reckoned to belong to it. Hence you may see how far we are from being certain how many Bodies belong to our own System.

M. From what you have said I am satisfied : For why should Bodies be conspicuous to us, for whose Use they were not originally designed ?

P. Consider also that, if they were conspicuous to us, they would not be adapted to the Use for which they were originally designed : For (as has been said) it is against the Order of Nature, that a *Secondary* should be equal, or nearly equal, to its *Primary*.

M. I remember still the *Mill-Stone* revolving about the *Pebble*, and perceive it is mere Unskilfulness to imagine that the *Secondaries* of other Planets might have been conspicuous to us. I would gladly know what those *other Bodies* are you mentioned just now ; but first let me ask,——

CIX. When

CIX. Why is it necessary that the Satellite of a small Planet should revolve so near it?

P. I expected to have heard the Reason of this from you.

M. By this gentle Reprimand I find I have been inattentive to the Consequences of what has been already said. The Reason seems to be, that a small Planet must have its attractive Force but weak, according to the Quantity of Matter it contains; and the Limit of equal Attraction betwixt it and the Sun at a small Distance from it. This will confine its Satellite to a narrow Orbit.

P. Could a Satellite revolve about its Primary at the Extremity of that Limit; or would it in that Case be equally, or nearly equally attracted to the central Body, in all Parts of its Orbit?

M. If we could suppose that the Satellite revolved near, or at this utmost Limit; in its opposition to the Sun, it would be attracted with more than all the Force of the central Body, the Sun's Action there conspiring; and in the Conjunction, it would be drawn with no Force at all; the contrary Actions of the Sun and primary Planet

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net there suspending each other. And this must prevent its revolving about a Center in any Manner; as it was in the Supposition we made at our last Meeting, where the *lower Body* was attracted by *that* above it, as strongly the one Way, as the *parallel Forces* impelled it the other. Whence it appears to me that a Satellite, in Order to revolve about its Primary with tolerable Regularity, must be placed a good Way within *this Limit*; that the Inequality of Attraction, in the Opposition and Conjunction, (which must still be something) may have the less sensible Effect.

P. What you say is strongly confirmed by considering the Systems of *Saturn* and *Jupiter*. All the Satellites in each of these roll at a vast Distance within the Limits of equal Attraction between the Sun and their Primaries. This is observable in their quick Revolutions.

M. I remember you said, the innermost of *Jupiter's* Satellites revolves about him in 42 Hours.

P. And a half.

M. At what Distance?

P. At a Distance from him nearly as great as our Moon is from the Earth; up-

on the Supposition that the Sun's Distance from us is about 21000 Semi-diameters of the Earth.

M. In what Time should it revolve about him at the Limit of equal Attraction?

P. It could not revolve at such a Distance, by what you observed just now: But supposing it to revolve at 80 Semi-diameters of the Earth within that Limit, it could not finish a Period about *Jupiter* in less than 700 Days, or near two whole Years.

M. There is a great Difference indeed between 42 Hours and a half, and 700 Days. The Light of it at such a Distance must be greatly diminished, I presume.

P. It would appear there perhaps but as a faint Glow-Worm in the Sky, hardly affording the 2900th Part of the Light which it shews him at present.

M. This is such a Light, I suppose, as a Candle would give at 2 or 300 Paces in a dark Night.

P. Here is a Figure, *Matbo*, of *Jupiter* and his four Moons, at their proportional Distances from him; and *this Arch* out here at the Extremity of the Paper,

G 4

shews

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shews the Limit of equal Attraction between him and the Sun.

M. I see it is a vast Way without the Orbit of his utmost Satellite.

P. It is distant from the Center of *Jupiter* about 159 of his Diameters; whereas his utmost Satellite is hardly 13 Diameters from his Center.

M. I am not only convinced in Reason, but this shews me in Fact too, that the secondary Planets must revolve a considerable Way within the Limit of equal Attraction between the Sun and their Primaries, in Order to move with no sensible Disturbance.

— But at what Distance might a *Secondary* revolve about *Venus*, or *Mars*, since it is supposed that each of these has a Satellite to attend it?

P. It is not so easy to give a positive Answer here, as we know not what Proportion the Quantity of Matter in either of these Planets bears to that in the Sun; for from the Quantity of Matter and Distance given, it is easy to determine the Point between any two Bodies, where their attractive Forces will be equal.

M. Yet I should think a probable Conjecture might be made, if we knew the

Magnitude of *Venus* or *Mars*, with Respect to the Earth; since it seems the Proportion between the Quantities of Matter in the Earth and Sun can be assigned.

P. By that Means perhaps we might come pretty near the Truth.

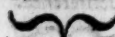
M. Is *Venus* less or bigger than our Earth?

P. Her Diameter is somewhat less, according to the most authentick Observations: But as the Bodies nearer the Sun are reckoned more dense than those farther removed from him, we may suppose that she contains the same Quantity of Matter that the Earth does. And then the Point, where the Sun's Force and hers would suspend each other, must fall about 31, 5 Semi-diameters of the Earth from her Center.

M. But a Satellite could not revolve about her at that Distance.

P. Nor a good Way nearer, without great Disturbance from the Inequality of Attractions in the Opposition and Conjunction. And though we should suppose a Satellite to move about her at 22 or 23 Semi-diameter's Distance; it could not appear to us farther removed from her than 12 or 13 Minutes; But in all Probability it is placed

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placed much nearer to her. What *Cassini* saw was not above two thirds of *Venus's* own Diameter distant from her; and very small, though well defined.

M. It is no Wonder that such a small Satellite, so near its Primary, should escape Observation.

P. As to *Mars*, the Quantities of Matter in the Earth and him, should be as 5, 6 and 1, according to their Diameters, which are nearly as 8 and 4, 5: But as the Earth is a little denser, it may be supposed to contain six Times the Matter in *Mars*. And in this Case, the Limit of equal Attraction between the Sun and him will be 27 Semi-diameters of the Earth from his Center; so that, if we suppose a Satellite to roll about him at 18 Semi-diameters Distance, it could not appear farther distant from his Center than six Minutes. But if it revolved at 3 or 4 Semi-diameters Distance only, which no Body will deny to be possible, and is much more probable (if we consider the innermost Satellites of *Jupiter* and *Saturn*,) that it might afford him the greater Light, and perform its Revolutions the sooner; it could not appear 2 Minutes distant from him. Add to this the

the proportional Smallness of such a Satellite, and it will be found almost impracticable to discover it. Now if it be but only possible that, though this Planet had a Satellite, it might not be discovered; there is no Reason for concluding, because no Satellite is discovered, that therefore *Mars* has none: And yet this is the only Argument for that Conclusion.

CX. *M.* I perceive the Strength of your Reasoning very well, and what Probability there is that *Mars* should rather have a Satellite than be without one. The Consideration of these Things is extremely pleasant; wherefore let me ask you, What would be the Consequence, or what Difference should we feel, if our Moon were removed to twice the present Distance from us?

P. We should not then have four *synodical Months* (as they are called) that is, four Conjunctions of the Moon with the Sun, in the whole Year: Nor should we only be without the pleasing Variety of shorter Months, but the Moon then could not afford us above the fourth Part of the Light we enjoy from her at present.

M. That

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M. That would indeed be a very disadvantageous Change. I have sometimes read a small Print by the Moon-Shine; but then I imagine the full Moon could not give us more Light than now she does three or four Days after the Conjunction. — How would Things be if she were carried off from us to four Times the present Distance?

P. If the Moon were but at twice the present Distance from us, *Matho*, according to your last Question, she could no longer revolve round the Earth as a Satellite; but below it, as an inferior Planet.

M. Well, leaving that Consideration,

P. If she were at four times the present Distance from us, we should not have a full Moon once in a Year; nor could she then give us above the 16th Part of the Light she affords us at present.

M. That must be but a melancholy State, when our Months would be as long as our Year, and our Moon twinkled dimly, like a distant Lamp in the Heavens.— But, on the other Hand, what Advantages should we reap if the Moon were but at half the present Distance from us: For, as removing her to a greater Distance, must diminish her Light, and lessen the Frequency

cy of its Returns ; so bringing her nearer us must have the contrary Effects.

P. It is so ; the Months then would be only about a third Part of our present Month, and the Moon would give us four times more Light than now : But as the *Tides* are occasioned by the Action of the Moon upon the Waters ; if she were brought within 30 Semi-diameters of the Earth to its Center, the *Tides* must swell to a prodigious Height. All the low Countries near the Sea-Coasts would be rendered uninhabitable, the Sea for many Miles overflowing them every Time the Moon passed our Meridian, either above or below. Our *Tides*, which now rise to 9 or 10 Feet, would then swell to 68, and in many Places to a greater Height. We can scarce figure to ourselves the Impetuosity of such a Heap of Waters setting in successively from the Ocean, on the Coasts, and falling back with equal Fury.

M. I conceive in some Sort, what Devastation this must make : As the Mouths of Rivers are on a Level with the Ocean into which they flow, the *Tides* would roll far into the Country, and all round must be an inhospitable Desert, neither Sea nor dry

dry Land, but a Scene of constant Horror, while the Floods rushed either the one Way or the other. How much happier then are we as Things now are ! May I ask you after this, What would be the Consequence to us, if the Moon's Distance were but a fourth Part of what it is ; or if she were within sixty thousand Miles of our Earth ?

P. Perhaps the Tops of the Mountains could hardly then afford a safe Retreat to the Inhabitants of the Earth from the tumultuous Sea. I mean it is to be feared, that then the Moon would draw the Ocean almost from its Bed, making it wheel round the whole Face of the Globe, in two opposite Tumors, or Mountains of Water, as the Earth revolved on its Axis the contrary Way. And if this were to be the Case, it nearly coincides with that terrible Disorder we observed before, when we supposed the first Impression of the diurnal Rotation made upon the solid Part of the Globe ; but not upon the Waters. Perhaps the Mountains themselves would in Time be dashed to Pieces, or washed down by the Fury of the rolling Floods, and our Planet reduced to a State of Confusion.

M. I see

M. I see the Consequences in both Cases are nearly the same: The not impressing the diurnal Rotation on the Waters there, and the Moon's impressing a contrary Force upon them here, must have had the same Effect.

P. It is likewise necessary here to observe, *Matbo*, that the Moon, in all Probability, is the largest Satellite in the System, in Comparifon of her Primary; it can therefore less bear her nearer Approach. The Satellites of *Jupiter* and *Saturn* are perhaps larger Bodies than the Earth itself; but still they are much less in Respect of their primary Planets. Therefore their nearer Attraction cannot disorder the Fluids of those Globes. And upon the same Account a Satellite of *Mars*, or of *Venus*, must be extremely little, compared with its Primary, in Order to roll about those lesser Planets at a small Distance.

M. I was going to ask you this very Question; namely, What would ensue if the Satellite were equal to its Primary? But you have prevented me. And besides, those Changes which we think only a Sport of the Fancy to imagine, draw deep, I see,
in

in their Consequences, and affect all Nature round us.

P. The Reflexion is extremely pertinent.

— If the Primary and Satellite were both equal in Magnitude and Density, the Distinction of *Primary* and *Satellite* would be lost. If their Distance were the same as at present, their periodical Time ought to be shortened, to increase their centrifugal Force; if their periodical Time were the same, their Distance ought to be enlarged to weaken their centripetal. If this were the Case between the Earth and our Moon, and if the present Proportion were once broke; we have no Notion on what Terms it could be healed again. One Thing however is remarkable in this Supposition: That both of them must then necessarily revolve about their common Center of Gravity, (equally distant, in that Case, from either): without Room for the Exception I made a little before. Now apply this to the Systems of *Saturn*, or *Jupiter*, where there are five or six Bodies: All these, if equal, ought to be equally distant from their common Center of Gravity, and therefore disposed in the Circumference of a Circle; and

and at equal Distances from each other in that Circumference. Thus rolling round *that Center*, and keeping still the same relative Situations with Respect to each other, there would be no Difference of periodical Months, nor Foundation for that Proportion between the Squares of the Times and Cubes of the Distances of Bodies moving round a Center; which, if I may so say, is the Key to all our Knowledge of the Motions of the celestial Bodies. Hence taking away the Distinction between *Primary* and *Satellite* would be of bad Consequence in many Respects.

M. I find, because we come into a World already prepared and habitable, we are not sensible what Art and Power it required to make it such as we see it: But from these Suppositions, and their Consequences, I perceive how many Ways it was possible for a Power and Knowledge less than infinite, to have miscarried in this complicated, mighty Design. A mere Change of Distance might have made that Moon, which now gently moves the Waters of our Ocean, and cheers our Nights, the Ruin of our Globe: And a Change of Magni-

MATHO: or, The

tude, all Things else remaining the same, must soon have subverted all Nature.

P. Nothing could better shew me, *Matho*, that you have a quick Sense of the Subjects we discourse upon, than the natural Observations you often make concerning them.

M. I am younger than you, *Philon*, and it is more natural for me to make these Observations, than for the greatest Philosopher.

P. What you say surprises me; pray shew me how that could be.

M. You Men have forgot your first Prejudices, and think always on the right Side: These Wonders therefore do not affect you so much. When we come into the World, and first begin to turn our Thoughts on the great Objects round us, we fancy the Constitution and Frame of Nature must be necessary: And when we take the first View of it, as the Effect of Art and Power, and see the Laws observed in the Contrivance, we feel the Opposition between our Prejudices on the one Side, and the Truth of Things on the other, in all its Force.

P. This seems not to be without Reason; but it reflects no great Honour on those
of

of riper Years, who either never made these Observations, or have now lost *that Sense* of Things which produces them. Eighth Conference.

CXI. But are you not already fatigued in pursuing these Matters?

M. Not in the least; something new always occurs from what we happen to talk upon: And now methinks I see the Reason why *Jupiter* is placed at such a Distance from *Mars*, and *Saturn* from *Jupiter*; as also, why the next inferior Planet to *these two* ought to have been but small.

P. What do you take to be the Reason of all these Things?

M. Those two huge Bodies, I suppose, with their Train of Satellites, must by their Attraction have disturbed each other, had not the Space between them been large enough to prevent that Inconvenience: And had the next inferior Planet been equal to either of them, that must have increased the Disorder. What you said a little before seems to me extremely reasonable, *That there can be no Chasms, nor unnecessary vacant Spaces in the System.*

P. Your Conjecture is confirmed by the Observation of Astronomers; for while

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those two uppermost Planets pass each other, notwithstanding their great Distance, they are observed somewhat to affect each other's Satellites. And had the Planet next to them (or indeed any of the inferior Planets) been equal to either of these, not only the upper Parts of the System, but the Center itself, would have been sensible of the Difference. When the Planets happened all to be on one Side of the Sun, and no Balance on the other, *Saturn* must have been more disturbed in his Course, and the central Body itself shaken.

M. Then it seems, placing the little Planet *Mars* in the Gap between our Earth and *Jupiter*, as also the whole Disposition of the Planets, was not merely arbitrary, and indifferent, as is generally thought, but the Result of pre-contrived Order and Convenience.

P. You will perhaps see more of this as you go on. When we have weighed Things maturely, and considered the Forces of the Sun and Planets, according to the known Laws of Gravitation; we shall find that this large Interval, which we may think employed to little Purpose, is in the main the greatest Frugality of Space.

M. You

M. You said just now that, were either of two attracting Bodies made larger, the periodical Time ought to be shortened to increase the centrifugal Force; or the Distance between the two Bodies ought to be widened to weaken the centripetal: Now, though you have already told me something concerning the Law of the centripetal or attracting Force; yet pray resume the whole Matter, and lead me into it in a familiar way, if possible.

P. Good *Matbo*, you are like to cut out more Work for us than, I'm afraid, either of us will be able to go through.

M. Enough of your Art, *Philon*, you have already, by your pretended Difficulties, screwed my Curiosity to the greatest Height.

P. I would do every Thing to oblige you, except spoiling a noble Subject, and making it more intricate, through my Want of Ability to communicate it to you easily: But since it must be so, let me first observe to you, that I shall be better able to explain these Particulars by bringing Examples, than by shewing you the Reasons of them from Nature.

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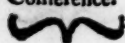
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M. Without apologizing for yourself, that is the fittest Method to be taken with me.

P. The centripetal Force, you remember, is the immediate Work of the Deity; and though he might have appointed other various Laws according to which Bodies might have gravitated to each other, yet this is the Law which for wise Reasons he has made to obtain, *That the Gravitation between two Bodies should always be inversely as the Squares of their Distances from each other.*

M. This I remember; but let me apply it to the several Suppositions we made before concerning our Moon, that the Thing may become more obvious. — If the Moon had been at half the present Distance from the Earth, she must have been attracted four Times as strongly by it, as now?

P. Certainly.

M. And then you say her periodical Time must have been but about a third Part of our present Month, in Order to increase her centrifugal Force, and prevent her being drawn down to the Earth?

P. It

P. It is so; our Month then would have been to our Month now, as 1 to 2, 828.

M. And her Celerity then must have been greater?

P. Without Doubt; as she performed near three Revolutions for one, and but at half the Distance.

M. Again, had the Moon been but at a fourth Part the present Distance from us, she must have been attracted sixteen Times as strongly as now?

P. You are right.

M. And our Month then must still have been shorter?

P. It must have been just an eighth Part of our present Month.

M. And therefore her Velocity must have been greater, to give her more centrifugal Force?

P. Unquestionably; for having sixteen Times more centripetal Force, her centrifugal Force ought to be increased equally, to prevent her being brought nearer the Earth.

M. On the other Hand, had the Moon been at twice the present Distance from the Earth, it must have attracted her but with a

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fourth

MATHO: or, The

fourth Part of the Force it does now; and we could not have then had four synodical Months (as you called them) in the whole Year; or her Celerity must have been less, to weaken her centrifugal Force, and bring it also to be a fourth Part of the former.

P. In all this you are extremely right.

M. And had she been four times farther removed from us, she must have been attracted but with a sixteenth part of the present Force; in which Case we could not have had a full Moon once in a Year; and her Celerity must have been so diminished, as to leave her but a sixteenth part likewise of her former centrifugal Force.

P. You remember the Case very well, and conclude very rightly.

M. From hence then it follows that, as Change of Distance from the attracting Body changes the centripetal Force; so changing the Velocity of the revolving Body changes the centrifugal.

P. It must of Necessity.

M. But as the centripetal Force is increased or diminished, inversely as the Squares of the Distances; is not the centrifugal Force also increased or diminished in a certain regular manner?

P. It

P. It is.

M. Now indeed I call to Mind the Instance of the Stone whirled round in a Sling, when you told me that the centrifugal Force was changed in a very regular manner.

P. You call to Mind that Particular very opportunely.

M. Pray then shew me after what Proportion it becomes greater or less; for I perceive, if we knew that, we might understand how it is that the two Forces balance each other; so that a Planet is neither drawn down to the central Body, nor flies out from it.

CXII. *P.* Here you must know that, though the Law of the centripetal Force be arbitrary, and might have been different from what it is, had it so pleased the Creator; the centrifugal Force, on the contrary, rises from a Necessity of Nature; or, to express it more justly, from the Resistance of Matter, by which a Body always tends to move on in a straight Line.

M. We talk'd of this long ago, when we first considered the circular Motions of the Planets.

P. Hence therefore a Body must resist being put out of its Direction (that is, it must

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must exert a centrifugal Force) not only according to the Celerity with which it is carried round; but also by so much the oftner as it is drawn out of its Direction by the centripetal Force in the same Time, or hindered from going on in a straight Line.

M. This seems plain; it must resist each Time it is pulled in, as it were, towards the Center; and if a Body is, by a repeated attractive impulse, four or five times drawn inward from its projectile Direction, in the same Time that another is but once diverted from that Direction, their Celerities being the same, it must have four or five times the centrifugal Force of the other. However as the centrifugal Force here depends on *two different Causes*, pray speak of them separately, that I may the more clearly conceive what Share each has in producing the Effect.

P. With all my Heart. Let us therefore suppose that another Moon, at a four times greater Distance than ours, were carried round the Earth in the same Time; and then tell me what Celerity she must have, with respect to the interior Moon?

M. Four

M. Four times a greater Celerity; because she moves round a four times larger Circle in the same Time.

P. The Periphery of it is certainly four times longer.

M. That is what I meant; for the circular Space itself is sixteen times larger.

P. Therefore as she moves with four times a greater Celerity, she must have four times a greater centrifugal Force; for she has four times a stronger Tendency to go on in a straight Line.

M. This I think I conceive: and if her Orbit were only twice as wide, she would have but twice the centrifugal Force of the inner Moon, because but twice her Celerity. For I suppose there are as many Deviations from moving on in a straight Line, in the Circumference of a less Circle, as in that of a greater.

P. Certainly; because the least returns back upon itself, as well as the greatest. And if you conceive a Compass so contrived, as to describe two concentric Circles at once; like Parts of both Circles require an equal turning round of the Compass; and therefore equally deviate from straight Lines.

M. Thus

M. So far I understand then; when two Bodies revolve about a Center in the same Time, and there is no Difference except in the Celerity, or Wideness of their Orbits, their centrifugal Forces will be as their Celerities. This likewise is the Case when we suppose the Earth to revolve about the Sun at a greater, or less Distance, still in the same Time: The centrifugal Force, and therefore the centripetal, is always as the Earth's Celerity in its Orbit, or as its Distance from the Sun.

P. The Application is very just.——But to come to the *second Cause* of, the Increase of centrifugal Force; suppose now that more Revolutions of the inner Moon were performed in the same Time: and the Reckoning will become different.

M. Give me an Example.

P. If the inner Moon, instead of one Revolution, performed two in the same Time; what Celerity must she have?

M. Twice her former Celerity; that is, half the Celerity of the exterior Moon.

P. And how often would she be retracted from going on in a straight Line, in these two Revolutions?

M. Twice

M. Twice as often certainly, as in one Revolution.

P. Join the Effects of these two different Causes together, and then tell me what her centrifugal Force will be?

M. Give me Time to consider this,——
In her two Periods she is twice as often retracted from going on in a straight Line, as in one; or twice as often resists being turned out of that Direction; and at each time with double the Force, because with double the Celerity: —— Therefore her centrifugal Force is twice double, or quadruple of what it was.

P. It is justly enough reasoned, *Mathe*; but could you not make it a little plainer?

M. I understand the Thing, but have not a Command of Words.—Twice the Number of Retractions in the same Time will make the Body resist twice as much being put out of its Direction, or exert a double centrifugal Force in the same Time; and double the Celerity will make it double of this Double.

P. This will indeed shew that in the whole Time of the two Revolutions, the Body exerts a quadruple centrifugal Force, of what it does when it performs but one
3. Revolution

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Revolution in that Time? But how will it shew that the Body exerts a quadruple centrifugal Force in any Instant of that Time?

M. Since the Body moves equally in its Orbit, or does not exert more Force in one Part than another; divide the Time into any Number of Instants you please, and the whole Sum of the centrifugal Force into as many Parts; and still the centrifugal Force in any Instant, when the Body performs two Revolutions, will be quadruple the centrifugal Force in the like Instant when it performs but one.

P. I perceive now you understand the Matter thoroughly; nor is the Argument different on any other Supposition: If the inner Moon is carried three times round instead of once, she must move with thrice the Velocity, and exert her Tendency of going on in a strait Line thrice as often; that is, she must exert thrice the triple of her first centrifugal Force in the same Time: Or her centrifugal Force is now nine times greater than it was.

M. Or if she performed four Revolutions for one, she must exert four times as often her centrifugal Tendency, with four times the Celerity; or have four times the Quadruple

druple of her first centrifugal Force. So that the centrifugal Force here increases with the Squares of the Number of Revolutions performed in the same Time.

P. That indeed is the Law, resulting, you see, from the Inertia, or Inactivity of Matter.

M. But a Body revolving about another, must either be drawn nearer to it, or carried farther from it, unless these two Forces, the centrifugal and centripetal, balance each other.

P. It must.

M. What Method can there be then of bringing them to an Equilibrium; since the one Force is *arbitrary*, and the other the *necessary Effect* of the Inertia of Matter?

P. A Method of accomplishing his Designs can never be wanting to the Deity: It is from bringing these Forces to an Equilibrium, *Matbo*, according to the different Distances of the Planets from the central Bodies, that the beautiful Proportion flows, which we have so often spoke of, between the Cubes of the Distances, and Squares of the periodick Times.

CXIII. M. Since

CXIII. *M.* Since therefore we have fallen so naturally into this Subject, pray take the Trouble to shew me how this Proportion results from bringing these contrary Forces to an Equality: For the Explication seems to follow easily from what we have already said.

P. It does indeed; nor should I think it a Trouble: But seriously I am afraid that so many new things will be apt to confound each other in your Memory.

M. Their Connexions and Dependence rather will bring them back in Order. Only go on in the same plain Method, and by the Help of Examples: This makes the abstract Reasoning more palpable, and hence the Things will stick better with me.

P. Well, since you will have it so, let us keep still to our two Moons, the one at four times a greater Distance from the Earth than the other; and if both revolved about it in the same Time, in what Proportion should their centrifugal Forces be?

M. The centrifugal Force of the more remote, as was said just now, must be four times greater than that of the *nearer*; as having four times the Celerity, and but once the

the Number of Deviations from the projectile Direction.

P. And in what Proportion should their centripetal Forces be?

M. Stay a little till I recollect. — The centripetal Force becomes greater, as the Square of the Distance becomes less. — It is so. The centripetal Force of the inner Moon, *Philon*, should be sixteen times greater than that of the *other*.

P. If then we suppose that these Forces are equal in the exterior Moon, what Difference will there be between them in the *nearer*?

M. Stay a little — The inner Moon hath sixteen times a greater centripetal Force, and only the fourth Part of the centrifugal. Bless me! How soon must she be drawn down to the Earth! — She has only the sixty-fourth Part of the centrifugal Force which she ought to have, that it may balance the centripetal, and keep her moving in a Circle about the Earth.

P. Explain this Point a little more distinctly, if you can.

M. These two Forces are equal in the exterior Moon: But the centripetal Force of the *nearer* is sixteen times greater than the *one* of them, and the centrifugal Force

only a fourth Part of the *other*. Wherefore it is plain that this last Force must be sixty-four times greater than it is (that is, sixteen times greater also than the centrifugal Force of the exterior Moon) that it may balance its contrary centripetal Force.

P. You have now made it plain enough: But how is her centrifugal Force to be increased, that it may become sixty-four times greater than it is?

M. Give me a little Time to think of it: This is pretty crabbed Work for a Beginner, — The centrifugal Force is increased with the Square of the Number of Revolutions performed in the same Time. — That Square ought to be sixty-four — Therefore the Number of Revolutions ought to be eight — I'm sure this is right enough. — Now, *Philon*, if the inner Moon performs eight Revolutions, while the outer Moon performs one, she must have her centrifugal Force equal to her centripetal, and neither be drawn down to the Earth, nor carried off from it, but return always in the same Track.

P. Notably done, *Matbo*! You have behaved like a Hero!

M. I am

M. I am glad of it; but here a Difficulty seems to occur.

P. What is it?

M. If one Revolution of this exterior Moon were only equal to eight Revolutions of ours, she must certainly be in Conjunction with the Sun in less Time than a Year: And you seemed to say the contrary when I asked you, What Difference there would be, if the Moon were at four times the present Distance from the Earth?

P. There is no Difficulty in this Case, *Matbo*: For though the *periodical Month* of a Moon at four times the Distance of ours should consist of about 218 Days; yet 327 Days more ought to pass, before she could again overtake the Sun, or get between the Earth and him. Because the Earth in the Interim must have moved a great way forward in its annual Course round the Sun: And it would not be enough for the Moon to come opposite to the Point where the last Conjunction happened; she must still move forward, 'till she get between the Earth and Sun again. Here her *synodical Month* therefore should be more than twice as long as her *periodical*; and consisting of about 545

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Days; two Lunations would hardly happen in three Years.

M. I have some Notion of this: The *periodical* and *synodical* Month would always be equal, if the Earth stood still: But as the Earth moves, the Moon has so much more to run over, after her *periodical* Month is finished.

P. It is so; and at present the *synodical* Month is about two Days longer than the *periodical*.

M. Well, to return;

CXIV. Let me consider what I have done, or how the Proportion between the Squares of the periodick Times and Cubes of the Distances appears from this Number of Revolutions.

P. You see the Distance of the interior Moon is 1, and of the *exterior* 4.

M. Right.

P. The Cubes of these are 1, and 64.

M. They are.

P. The periodick time of the interior Moon is 1, and of the *exterior* 8.

M. Certainly; since the one is eight times the other.

P. But

P. But the Squares of these are likewise
1 and 64.

M. O *Philon*! You have made me happy! For it was the Height of all my Wishes (if I may say so) to understand this; and now I do understand it. This is not only an Example of the Proportion; but it shews from the Nature of Things, how these Motions must be in this Proportion.

P. This is the Law, *Matbo*, which obtains in the Motions of all the Primary Planets round the Sun; and also in the Motions of all the *Secondaries* round the same Primary.

M. I remember you told me that they who placed the Earth in the Center of the System, and supposed the Sun to revolve about it, in the fourth Place (namely, above the Moon, *Mercury* and *Venus*) confounded this beautiful Law of the planetary Motions.

P. They do Violence to Nature itself; since the centrifugal Force, or the Resistance of Matter on which it depends, is stubborn and unyielding: For, let us suppose that the Distance of the Sun from us was but 12000 Semi-diameters of the Earth, or 200 times the Distance of the Moon; and then

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the Cubes of their Distances will be 8000000 and 1: The Square-Roots of which Numbers are 2828 and 1. So that the periodical Time of the Sun ought to be 2828 times that of the Moon: That is, either our present Year ought to contain 2828 Revolutions of the Moon, each consisting of about three Hours, six Minutes; or our present periodical Month ought to be but the 2828th Part of the Year; whence one Revolution of the Sun would be equal to 211 of our present Years. Either of which is monstrous.

M. Those Philosophers are as far wrong in this Respect, it seems, as in supposing that such a small Body as the Earth could resist the attractive Force of the Sun and Planets, without being drawn from its Place.

P. They might easily be excused, *Matbo.* in not discovering this Law of the celestial Motions; but not to own the Mistake they were under, after it was discovered, is something worse than Ignorance.

M. Pray give me another Example of this Proportion, that I may apply the same Reasoning to Bodies revolving at other Distances.

P. Suppose

P. Suppose two Planets revolving about the Sun, the one 5 times more remote from him than the other, which is nearly the Case between *Jupiter* and our Earth; and then —

M. Permit me to go on with the Argument my self. — The Earth, being but at a fifth Part the Distance, will have 25 times more centripetal Force than *Jupiter*; and, if they had performed their Revolutions in the same Time, it must have had but a fifth Part his centrifugal Force. Therefore, if we suppose these two Forces to balance each other in *Jupiter*; when the Earth has got five times more centrifugal Force than it hath, it will still have but the centrifugal Force in *Jupiter*, or the 25th Part of what it should have, that its centrifugal Force, as well as centripetal, may be 25 times that in *Jupiter*, and consequently the one balance the other.

P. You express the Matter very clearly: Go on.

M. Since the Earth must have 125 times more centrifugal Force than it has, that Number 125 must be the Square of the Number of Revolutions which it performs in the same Time that *Jupiter* performs one;

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or it must perform some more than eleven
Revolutions for *Jupiter's* one; for 121 is
the Square of 11.

P. The Square-Root of 125 is 11, and
about two tenths.

M. Then the Distances being 1 and 5,
the Cubes of these are 1 and 125; and the
Times being 1 and 11,2; the Squares of
these are likewise 1 and 125.

P. All this is perfectly right, *Matho*; and
on this Supposition you see *Jupiter's* periodic
Time must be some more than eleven Years;
But had we taken the Proportion of the two
Distances more exactly, which is somewhat
greater than that of 5 to 1, *Jupiter's* peri-
odical Time would have been 11 Years and
about 314 Days, which it really is. How-
ever it was needless to have affected such
Nicety, which must have engaged you in a
more tedious Computation; since the Reason
of the Thing appears as well from one Di-
stance as another.

M. As this Proportion holds in the Moti-
ons of all the Planets revolving about the
Sun, I shall try the Computation by my
self; since I have their Distances and peri-
odical Times in the first Diagram you gave
me,

P. By

P. By that Means you may make this fundamental Theorem familiar to your self.

M. As to its being *fundamental* I am not yet so good a Judge: But certainly it is an amazing Instance of the Power and Wisdom of the Creator, to impress these different Forces on the same Bodies in such a Manner, that while the *centripetal* always impells the Planets inversely as the Squares of their Distances from the central Body; the *centrifugal* is proportioned to it in that only Quantity, by which a circular Orbit could be described!

P. Let those Persons, *Matho*, look to these Motions of the Sun, Moon, and Planets, who suppose that the *Deity* must be an indolent and slothful Being; or perhaps only a mere Name, and State-Trick of the first Legislators, to fright Men into a Compliance with their Schemes.

M. O strange! *Indolent*, or a mere Name! What Proof of *almighty Power* would they have; or could they comprehend? Are not these Motions exposed to the Eyes of all? Or would it satisfy them that there were an *all-powerful Being*, who preserved the World, if the heavenly Motions were stopt, and Nature went into Confusion?

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P. You have Reason to ask this contradictory Question: For when Men refuse their Assent to the most plain and natural Proofs, it looks as if they would be satisfied with their Contraries; that is, with no Proof at all; or rather that they are resolved not to be satisfied,

CXV. M. Since it is certain from *Observation*, that the Squares of the Times of the Planets round the Sun are as the Cubes of their Distances from him; and since you have shewn me according to what Law the centrifugal Force is increased or diminished; I now see plainly, and any body may from thence gather, that their Attraction toward the Sun is inversely as the Squares of their Distances from him.

P. Shew me how you collect this?

M. The centrifugal and centripetal Force of any Body describing a circular Orbit about another, must be equal: But by examining the centrifugal Forces of any two Bodies, according to the Rules you have explained to me, I find these are inversely as the Squares of the Distances of the two Bodies from the central Body. Therefore I conclude, their
centripetal

centripetal Forces, which are equal to these, must be in the same Proportion.

P. Your Argument is good ; but apply it to some of our former Examples.

M. In the Example of our two Moons, one at a four times greater Distance from the Earth than the other, the nearer Moon hath double Celerity, and deviates eight times oftener from the projectile Direction in the same Time, than the *exterior*: Hence she must have sixteen times more centrifugal Force, and therefore sixteen times more *centripetal*, than the Moon at four times the Distance. And from this I now see that the Proportion between the Squares of the Times and Cubes of their Distances is indeed a *fundamental Article* in order to understand the Law of the Planetary Motions.

P. It is as you say ; from that once discovered the rest becomes easy.

M. I am likewise satisfied from this Argument, *viz.* Since the Squares of the periodical Times of Satellites revolving about the same *Primary*, are as the Cubes of their Distances from it ; that they cannot be more, nor so much attracted to any other Center, as to that of the Planet about which they move. For if they were but equally attracted

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tracted to another Point, their Attraction to that Center would be nothing at all, instead of being inversely as the Squares of their Distances: Whence that Proportion must be spoiled.

P. You are right: since *no Attraction at all* could have given Foundation to *no Proportion at all*. —

M. But you said that other Laws of Attraction might have been appointed by the Creator, had he so pleased.

P. Surely; for the Attraction might have been directly as the Distances, or inversely as the Distances; or directly as the Square-Roots of the Distances, or inversely as the Square-Roots of the Distances, with an endless Number of other Suppositions, which were all equally possible to the Deity, though not equally convenient for the Nature of his Work.

M. Pray give me an Example of this, that I may see the Difference between any of these, and our present Constitution?

P. You need only to be put in the Way, to pursue any of these Cases by your self. Tell me then, if the Attraction had been directly as the Distances, and one Planet had been removed to twice the Distance of another

ther from the Sun, in what Proportion would their centripetal Forces have been?

M. That at twice the Distance must have been twice as strongly attracted; according to its double Distance, to wit.

P. And their centrifugal Forces?

M. These must have been in the same Proportion, to balance their contrary centripetal Forces; if they were both to move in circular Orbits.

P. By what Means could the Planet at double the Distance have had double the centrifugal Force, to balance its double centripetal Force?

M. If it had performed a Revolution in the same Time, its double Celerity must have given it a double centrifugal Force. For on this Supposition the centrifugal, as well as centripetal Forces must have been as the Distances. And — at this Rate — all the Planets must have revolved about the Sun in the same Time: For then their centrifugal Forces must all have been as their Celerities, or Distances from the Sun.

P. It is so; the outermost *Saturn* must have performed a Revolution, as soon as the innermost *Mercury*.

M. Let

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M. Let me go on; I think I see still something farther. In that Case they could never have changed their relative Situation with Respect to each other; *Saturn* or *Jupiter* performing half, or any Part of a Revolution, as soon as *Venus* or *Mercury*. And if at the Beginning of their Motions, some Bodies had been placed on the opposite Side of the Sun, with Respect to others, they could never have had Sight of each other, but always remained in that Opposition, obscured by the Sun's Rays. Or had an interior Planet been placed directly between another and the Sun, it must still have appeared as a Spot upon his Disk. In short, our present Constitution seems every Way preferable to this.

P. It is likewise more natural, *Matho*, that the Attraction should go on decreasing from the Sun, as well as the Heat and Light, and decreasing in the same Proportion; rather than increasing. — Again, If the Gravitation to the Sun had been inversely as the Distances, what must have been the Consequence?

M. A Body at half the Distance must have been doubly attracted, and ought therefore to have had double the centrifugal Force of another at the whole Distance.

P. And

P. And if they had performed their Revolutions in the same Time?

M. The innermost could have had but half the centrifugal Force of the other; or one fourth of what it should have had.

P. How could it have got four times as much centrifugal Force?

M. If it had performed two Revolutions for one. And from this I see the rest: For since the interior Orbit was half the exterior, and the interior Planet revolved twice in the Time the exterior revolved once, their Celerities must have been equal, and therefore their periodical Times directly as their Distances from the Sun.

P. You are perfectly right. If this had been the Law of Gravitation in our System, the Celerities of all the Planets must have been equal, and their periodical Times as their Distances. *Jupiter* must have performed a Revolution in some more than five Years, and *Saturn* in something less than ten.

M. I am delighted with this sort of Reasoning, and fancy, without giving you more Trouble, I shall be able on any other Supposition to draw the Consequences for my self, and find out on what Terms the centripetal

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centripetal and centrifugal Forces are to be brought to an Equilibrium, so that the Body should describe a circular Orbit.

P. It will not be difficult.

CXVI. *M.* I now begin to understand what I desired to be informed of in the beginning of our Discourse; namely, That all these sixteen Bodies could not have revolved about the Sun immediately, as the Center of their Motion, without great Inconvenience.

P. In what Respect?

M. The more remote Planets must then have been deprived of their Moons, which, by reverberating the Sun's Rays upon them, diversify and cheer their Nights.

P. They would likewise have suffered another Loss, *Matho*, not inferior to this, in that the exterior Planets must have been removed to a much greater Distance from the Sun.

M. I have a Notion why this must have been; but pray assist me.

P. Our Moon, for Instance, by revolving about the Earth, as a Center, must necessarily be brought near it, that she may be within the Bounds of its stronger Attraction: But had she revolved directly about the Sun, she

She must as necessarily have been removed to a great Distance from the Earth, that she might have been on the other Side of that Limit; lest the prevalent Attraction of the Earth should have disturbed her Motion, or drawn her the contrary Way.

M. This is indeed very obvious from what has been said before: She must have then rolled a considerable Way without that Limit, as now she moves within it.

P. If then we consider *Jupiter* and *Saturn*, those larger Planets, attended each with a System of Satellites; their Moons, in this Case revolving separately about the Sun, must have been removed to a vast Distance from them.

M. To a vast Distance certainly, if (which seems reasonable) they ought to have been placed as far without the strong Force of these huge Bodies, as now they are within it. For in those remote Regions, where the Sun's attractive Power becomes comparatively weak, the Force of *Jupiter* and *Saturn* reigns far and wide.

P. We may in some measure guess to what a Distance their Satellites ought to have been removed from such huge Bodies, in that Case; when we consider that they

disturb each other's Satellites at an immense Interval in the present Disposition.

M. That I did not think of: I find now you had good Reason to say, *That the large Interval, which we may think laid out to little Purpose, is notwithstanding, when maturely considered, the greatest Frugality of Space.* Any of the Satellites of these great Bodies must then have been as far removed from either of them, as now the Bodies themselves are distant from each other.

P. If therefore all the Planets, as well Secondary as Primary, had revolved about the Sun separately, as the immediate Center of their Motion, *Saturn*, you see, must have been removed much farther from the Center than at present, and the Bounds of the whole System greatly enlarged.

M. To near double, I presume; and the periodical Times of the Planets must in Consequence have also been lengthened, according to the Proportion we have spoke of.

P. Without doubt: Had *Saturn* been at double the Distance, he could not have completed his Revolution in less than eighty-two Years.

M. Hence

M. Hence I see then, if all these sixteen Bodies had revolved separately about the same common Center, as now the Primary Planets do, they must have suffered two Losses equally great; having the Heat and Light of the Sun more faint and languid by Day, and no vicarious Luminary to supply his Place by Night.

P. All that Variety of Light, *Matbo*, we so much admired before, all those Vicissitudes, and glorious Phænomena in the Heavens, are quite extinguished on this Supposition.

M. In Truth I think it is hardly possible to consider the present Disposition of the System, and how useful the several Bodies in it are to each other, without being full of a Sense of Love and Gratitude to the Creator, for his indulgent Care and Provision. Were we deprived but of our Moon, it would not be easy, I believe, to find out all at once the several Losses we should suffer.

P. It is reasonable to think, we could only discover some of them by feeling them.

CXVII. *M.* What we have said just now suggests a Reason, I think, Why the

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uttermoſt Planets ought to have been larger than thoſe nearer the Sun.

P. For what Reason then doth it appear to you that this was ſo ordered?

M. By how much the exterior Planets were to be more diſtant from the Sun, ſo much the more were they to ſtand in need of the Relief and Comfort of thoſe Satellites, or vicarious Luminaries: And had they not been prodigiouſly large Bodies, in reſpect of the interior Planets, their attractive Force could not have been ſtrong enough to keep each of them a Syſtem of Moons rolling about it ſelf.

P. I am entirely of your Opinion. *Saturn* we ſee, in the utmoſt Regions of the Syſtem, is able to retain five or ſix ſecondary Lights rolling round him; and *Jupiter*, though near about the middle of it, keeps four: Whereas had any of the four lower Planets been ſet off to the utmoſt Parts of the Syſtem, they could hardly have retained one Satellite, againſt the Attraction of *all the great Bodies* lying near the Center. We may imagine that great Bodies placed near the Center might have been more proper and uſeful; but we do not conſider the Inconvenience of ſuch a Diſpoſition. The Syſtem
in

in that Case could not have consisted of near so many Bodies, nor those near so useful to one another.

M. Besides the Inconvenience, the present Order seems more agreeable and decent. It would have had the Appearance, in some sort, of Neglect and Carelessness, had the lesser Planets been thrown to the out-side: But these larger Bodies inclosing the System look stately and magnificent.

P. Add to this likewise, *Matbo*, (since the Celerities of the Planets are reciprocally in the sub-duplicate Ratio of their Distances from the Sun;) that it must have appeared against the Order of Nature for such a mighty Body as *Jupiter* to have been carried round with the rapid Motion of *Mercury*; or that *Mercury*, *Venus*, or our Earth, should have moved at the slow Rate of *Saturn* or *Jupiter*.

M. It does not indeed seem natural for a Body to move the faster, the larger it is: But explain a little, if you please, this Proportion of the Celerities of the Planets.

P. I dare say, if you consider it, you will be able to make this out by yourself.

MATHO: or, The

M. The Truth is, I do not understand what you mean, by being *reciprocally* in the *sub-duplicate Ratio* of the *Distances*.

P. That is only, that the Celerities of the Planets are inversely as the Square-Roots of their Distances from the Sun.

M. This is more intelligible, and now I fancy I can deal with it, by the Help of our former Example of the two Moons. — The *interior* had her Orbit but a fourth Part of that of the *exterior*, and she performed 8 Revolutions for the other's one; so that her Celerity was double that of the other: Of their Celerities were as 2 and 1. But 2, the Velocity of the *nearer*, is the Square-Root of 4, the Distance of the *more remote*, that is, their Velocities were inversely as the Square-Roots of their Distances.

P. I find I was in the wrong, *Matbo*, to affect such a learned way of Speaking; Good Sense has not fair Play, when it is oppressed with hard Words; But I shall be on my Guard for the future.

M. If then the Distances of the Earth and *Jupiter* from the Sun were as 1 and 5, their Celerities would be contrarily as the Square-Roots of 5 and 1,

P. You are perfectly right; and it is so in all other Cases. —

M. Leaving this, pray let me observe to you, lest I forget it, one singular Advantage with respect to the shortening the Darkeness of our Nights here on this Planet, which I have often thought of by my self.

P. What is it?

M. I understand from what we said formerly, concerning the annual and diurnal Motions of the Earth, that we are exactly half the Time in the Rays of the Sun, and the other half in the Shade of the Earth: And yet a great deal more than the half of our Time is Day-Light, if I may so express it; for if we take in our *Morning-Dawn*, and *Evening-Twilight*, they shorten the dark Half of our Time, by at least three Hours every Night.

P. This, among many others, is an Advantage we reap, *Matbo*, from the Constitution of our *Atmosphere*, which spread round the whole Earth, does the Office of a Moon for some Hours every Night, by reflecting the Light of the Sun in upon the Globe it surrounds. Were it not for this Contrivance, intense Darkeness would succeed to the Sun-Light, not gradually as now, but in an In-

stant: And contrarily, the Light of the Sun to intense Darkness. The Traveller would be benighted in a Moment after losing Sight of the Sun: Nor in the Morning should we be able to bear the sudden Change from thick Shades to bright Sun-shine. It would be like bringing a Man from Confinement in a dark Dungeon, all of a sudden into open Day.

M. O the Goodness of the Creator! As Light is a precious Thing, how many wonderful Ways has he taken to supply it to his Creatures! Who of a thousand thinks now on this Advantage? It seems to be one of those Cases, where we could only discover our Loss by feeling it.

P. We are graciously prevented with the Comforts of Life; and therefore, as you observed a little before, we imagine Things could not have been otherwise than they are.

M. I remember you told me before that our Atmosphere is a *Scene of Wonders*; and I think this is one, *That the Air should be so transparent and pure, as to transmit to us the Light of the fixt Stars; and yet so gross (if I may use that Word) as to reflect on us the Light of the Sun when absent.*

P. The

P. The Air that surrounds our Globe, *Matbo*, is as necessary to our Support, as the Globe itself. This elastick Fluid is to us the Breath of Life: It is in all the Parts of our Bodies, and by a Counter-Pressure which we feel not, preserves them constantly from being crush'd: It is many Ways absolutely necessary to Vegetation; the Vehicle by which Dews and refreshing Showers are conveyed to the otherwise barren and thirsty Mold; and with all this it is the very Spirit of Fire and Flame, without the Use of which Life would be miserable.

M. I see on every Hand by what Instances of Power and Kindness the Creator hath guarded his Works against the Exceptions of ignorant Mortals: All this is performed by Means of an Element, which we think scarce deserves our Attention.

P. It is true; but in the Nature of Things there is no guarding the Works of Knowledge against the Calumnies of Ignorance, since the more artful the Performance is, the more such People carp at what they do not understand. Let us leave them then to the Reproaches of their own Mind, to which a small Acquaintance with the Works of Nature will expose them. —

M. I was

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M. I was going to ask you about the Elasticity of the Air, and why you think it is in every Part of our Bodies; but I am afraid of troubling you.

P. A few plain Experiments will make you know more of the Elasticity of the Air, than I can tell you. The Weight of the Atmosphere is balanced by this Repellency between its least Parts. The Pressure of it therefore upon all the Parts of our Bodies, is counter-poised by this Repellency of the Particles in all Parts of the Body; and not at all by our soft Flesh, and less by the Repellency of the outward Particles, one against another; because the Surfaces or Figures of our Bodies are not fitted to that Purpose. When the Pressure is taken off one Part of the Hand, by laying it on the Mouth of a Glass out of which the Air is drawn, we feel a great Force and Pain. This is because the internal Particles have nothing to act against. We should feel an equal Pain at all Times, and in all Parts of our Bodies, were it not for these: The Repellency of the external Air has no Share in this. When the Glass from which the Air is drawn out, is of an irregular Figure, it is shivered to Pieces

Pieces in an Instant *. When Men dive to such Depths in the Sea, that the internal Particles of Air are crowded into half the Room, they feel great Pain. This is confirmed likewise from what happens in the Diving-Bell: But these Things would require more Time and Words.

M. Nay, *Philon*, I am now more than content to leave you: You talk away so fast, that you are quite out of my Sight.

* When the Air is exhausted out of the *Glass Receiver*, there is a prodigious Pressure on all the Parts of it quite round. The mutual Repulse between the Particles of the external Air does not keep off this Pressure, or form an artificial Vault to preserve the Glass. It bears this Pressure by the Advantage of its Figure; as an Egg, pressed equally at both Ends, bears a great Force. Our Bodies therefore suffer a Pressure at all times equal to what the exhausted Receiver does. And neither the Figure of our Bodies, which is constantly changing while we move, or breathe, nor the firm Texture of our Flesh, is fitted to bear this constant and vast Weight. And though either of these were the Cause, we should nevertheless feel always an excessive Pain. It must be a Spring therefore, both more powerful and artful, which counter-acts this Pressure, and prevents the fatal Effects it would otherwise have. And this Spring can be nothing but the Particles of the Air it self in all Parts of our Bodies, as was said. It is impossible to reflect on this without Amazement!

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What must have been the Consequences if the Moon had moved in a Plane crossing the Ecliptick, or Plane of the Earth's Orbit, at right Angles. That our Earth is a Moon to its own Satellite, appearing to her near 16 Times larger than the Sun himself, and thereby throwing on her a vast Gleam of Light. Jupiter appears to the innermost of his Satellites 1600 Times larger than the Sun does to us; and Saturn more than a 1000 Times larger to his nearest Satellites: They must therefore throw a prodigious Splendor on their own Moons. That the Planets both Primary and Secondary are thus carefully illuminated, shews they are not empty Seats; but designed for Habitation: For Light, in the Nature of Things, answers to Eyes. A skilful Artist could not design that which is more noble for the Use of

of what is of an inferior Nature. The whole material Universe was therefore made for the Sake of Rational Beings. That our Sun at the Distance of Sirius or Arcturus would appear but like one of the fixed Stars, and the solar Planets be quite absorbed by the immense intervening Space. The great centrifugal Force on the larger Planets a Relief to their Inhabitants, as suspending a considerable Part of their Weight on these vast Bodies. The Density of those great Bodies wisely contrived in being less than in smaller Bodies, upon this Account. An easy Way to calculate their Quantities of Matter and Denfities.

CXVIII. P. **Y**OU must have grown familiar with the Planets and their Satellites, *Matbo*, if you have past all your Time, since I saw you last, in the Regions above.

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M. Sometimes above, and sometimes below; but Familiarity, you know, is not so soon contracted in a strange Country: Besides, you may easily guess from the Heads of our last Conference, that my Business in those Places was both various and difficult.

P. All

MATHO: or, The

P. All is well now, I hope?

M. All is so far well, that I have a tolerable Notion of what we were then upon; But other Things still occur which puzzle me.

P. It must be so with Beginners, till they have gone through the whole Scheme, and see the Consistency of one Part with another. But what are those Particulars that puzzled you most?

M. Before we speak of any Thing else, I must acquaint you, that an Expression you dropt at our last Meeting has exercised my Thoughts ever since.

P. What was it?

M. When we had observed, that the shortening the Distance between the Sun and Planets seemed by all Means possible to have been studied by the great *Architect of Nature*, and had talk'd of the Number of Bodies that compose the Solar System, you added, that all the Planets revolved about the Sun nearly in the same Plane; but that there were other Bodies, more in Number, which traversed the System all Manner of Ways. This, as I thought, you seemed to say, with a View to prevent an Objection, namely, Why the Sun might not

not have been beneficial to more Bodies, which might have revolved about him cross-wise, or in a Plane crossing the other at right Angles? This brought to my Remembrance a Particular you hinted at long agoe, when you seemed to conclude (from the Motion, I suppose, of some particular Bodies,) that the Attraction of the Sun reached a great Way into the Regions above *Saturn*, or between his Orbit and the fixed Stars. You awakened my Curiosity then, and have never satisfied me since; wherefore I beg you would inform me, what lies concealed under those distant Hints.

P. When I have told you all I know concerning these Things, you will hardly think it worth your While.

M. But pray acquaint me with it, whatever it be.

P. If there be any Thing else you would discourse of, let us speak of that; and I shall readily inform of what I know about those Matters, if an Opportunity should offer naturally.

M. Next then, with Respect to the Planets lying all in the same Plane nearly, (namely, that of our *Ecliptick*) I was trying to find what would have been the Consequences,

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sequences, if the Orbit of our Moon, for Instance, had lain in a Plane crossing the Plane of the Earth's Orbit at right Angles: But I could neither imagine the Case exactly, nor find out a Reason why it might not have been so in Fact.

P. It is enough in such Cases, *Matbo*, that we see the present Disposition wise and regular; nor are we to imagine that we can come at the Knowledge of, or discover all the Reasons why Things were ordered so. *That*, as we have observed, may lead us into fatal Mistakes.

M. I remember well enough the impious Notion, That one might have taught the Deity how to mend his Work.

P. We plainly see great Inconveniencies from some Dispositions, differing from the present, that were equally possible: This shews us the Kindness and Wisdom of the Creator, in the present Order and Motions of the heavenly Bodies. But supposing other Dispositions might, in some Respects, have been equally advantageous for us; What then? We have nothing either to complain of, or carp at, because the Deity hath chosen one of two Ways which were equally proper. And yet in the present Case,

Case, it is certainly more orderly and beautiful, that all the Bodies in the System should lie in the same Plane, and move the same Way (according to the Order of the Signs) as it were in concentrical Circles; than that their Orbits should have lain across each other, and taken up the whole Space; though we should not know for what other Purpose the Creator may have reserved it free.

M. All this I agree to: Yet there is no Harm in endeavouring to conceive what Appearances would have been, had the Planes of the Moon and Earth's Orbits been at right Angles to each other.

CXIX. *P.* That might have been many different Ways. Had the common Section of the two Planes always passed through the Center of the Sun, the Moon would then indeed in every Revolution have been in Conjunction with, and Opposition to the Sun, as now: As also this Plane lying through the Sun and Earth, she could never have been before, or behind the Earth in its annual Course, but still equally advanced with it. Thus far you conceive?

M. Easily; for this Plane standing erect above the other, like the Leaf of a Book, must have moved round as the Earth moved, so as to pass always through the Centers of the Sun and Earth: But still we should have had our full and new Moon regularly as at present.

P. Hold a little. — Then you will allow, since this Plane stood erect above the other, like the Leaf of a Book, that the Way of the Sun and Moon must have lain perpendicularly to, or across, each other?

M. Right; for then the Moon must have come over our Heads from North to South, or from South to North at least.

P. She must certainly have passed thro' the Poles of the Ecliptick; and consequently, through or near the Poles of the World.

M. Let me consider this Circumstance, — I see the Plane of her Orbit must always have passed through the Poles of the Ecliptick; — And since our elevated Pole always points to the North, her Plane must have passed through the Poles of the Equator too, when the Earth was in the Solstices; for passing still through the Center

of the Sun, it must then have lain directly South and North. And at all other Times it must have passed a little besides the Poles of the World.

P. Then the diurnal Rotation of the Earth could not have caused the Moon to rise and set to us every Day, as she does now; for when she was about the South Pole, we could not have seen her for many Days, more than now we see the Southern Constellations, which never appear above our Horizon. And besides, she must have lingered long about the gloomy Horizon, either in coming in, or going out of Sight, having but twelve Degrees of meridian Altitude the first Day of returning from the South, and twenty-four the next.

M. I was not aware of this. It is strange enough. All the Time likewise she should be about the northern Parts of the Globe, she must be hid to those lying on the other Side the Equator; and the most constant Part of her Light must have been shed over the frozen Regions of the Earth, where there are few Creatures, at least rational Inhabitants, to perceive the Benefit of it. This must have been a palpable Miscalculation, to make the Light of the

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Moon take a different Course from the Light of the Sun, and so leave the populous and habitable Parts of the Globe worst provided for.

P. There is still another Inconvenience, not less than this: For since the Moon must always have moved upon (or near) a vertical Circle, passing through the Center of the Sun, she must for half of her menstrual Course have come to our Meridian almost at the same Time with the Sun, or about twelve o'Clock of the Day: That is, our Moon-Light must have happened, for the half of her Revolution, by Day; when it could not have been perceived, nor done us any Service.

M. It must indeed have been so, since the Half of that Circle must have come above, or fallen below our Horizon, nearly with the Sun; which would have been a disadvantageous Change to us in Point of Light and Variety.

P. Things would have been different from what they are in most other Respects: Our periodical and synodical Months would have been the same; and the Tides must have swelled for some Days together about either Pole, once a Month, without a Tide

on the opposite Part of the Globe, as now; and there must have been an Eclipse of the Sun every Conjunction, and of the Moon every Opposition.

M. I understand; it must have been so, because the Plane of the Moon's Orbit passed through the Centers of the Sun and Earth. —And these several Circumstances may, I think, suggest to us the Inconveniencies we should have suffered, if not the Moon, but the Earth itself, had thus moved from North to South, instead of moving from West to East, which certainly was not impossible.

P. That the Equators of the diurnal Motions of all the Planets were nearly obverted to the Sun, was Matter of Choice, and not of Necessity. Had the Way of the Sun lain through the Poles of the Earth, as you suppose, the Consequences must still have been more inconvenient.

M. We never consider these Cases as possible; and hence it is that we never contemplate the Wisdom and Kindness of the Deity in the present Constitution.

P. I am perfectly charmed, *Matbo*, with your pertinent and rational Reflections: The greatest Philosophers lose the best Part of their

their Pleasure arising from the Study of Nature, for Want of such Observations. —

M. The Consequences of this Supposition I shall endeavour to find out by myself, since you have put me in the Way: But you said the Plane of the Moon's Orbit might have lain across the Plane of the Earth's Orbit many different Ways.

P. It might not have lain through the Sun, but parallel to his Disk, or at right Angles to itself in the former Position: And then it must also have gone through the Poles of the Ecliptick, and those of the Equator likewise in the Equinoxes.

M. It must, as lying then directly North and South; or being every where at right Angles to itself, as in the former Supposition.

P. In this Case the Moon would sometimes have been before the Earth in its annual Course, and sometimes behind it, as at present; but could never have come into Conjunction with, or Opposition to the Sun, but have always kept at an equal Distance from him,

M. This Supposition is, I think, still worse than the last, since the Moon then must not only have spent a good Part of her
men-

menstrual Revolution about the Poles of the Globe, but could never have shone upon us with her full Lustre, as never coming to an Opposition with the Luminary from which she borrows her splendor.

P. And worse likewise, in that being now attracted by the Sun and Earth in two different Planes, her Motion must have become quite perplexed and irregular.

M. Pray help me to understand this ?

P. You know the Plane in which she is now supposed to move, standing erect, like the leaf of a Book, to the Plane of the Earth's Orbit, and not passing through the Sun; his whole Force must then have been exercised to bring down that Plane nearer to the Earth's; and that on whatever Side of the common Section of the two Planes she was.

M. I conceive it; in the last Supposition, where the Plane of her Orbit passed through the Sun, he must have accelerated her in her Course, but could not have drawn her out of the Plane in which she moved; whereas here the Lines by which she is attracted to the Sun and Earth, could never be in the same Plane, except when she was in the Intersection of both Planes: Which

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must make her dip, or move in no certain Plane. And as she would be drawn forward or nearer the Sun, the farther she moved from the common Section on either Side, we should still lose more of her Light.

P. You hit the Case perfectly: She could never be attracted by Lines in the same Plane, except when in her *Nodes* (as they are called;) and a small Digression of this Sort at present causes a considerable Irregularity in the Moon's Motion. — And, as I said, there are innumerable other Positions between *these two*, in any of which the Plane of the Moon's Orbit would have been erect to that of the Ecliptick: But as they had been near the one or the other of the two Positions we have spoke of, so they must have participated of the Disadvantages proper to either the first or the last.

CXX. M. You have now, *Philon*, been better than your Word. I not only myself understand the Beauty and Usefulness of the present Disposition, but could even shew to another the Inconveniency and Loss we should have sustained, had the

the Plane of the Moon's Orbit crossed that of the Ecliptick. And the same Reasoning seems to be applicable to the Moons of other Planets, which must have been less carefully provided for, had the Planes of their Satellites lain across the common Plane.

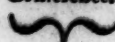
P. There is all the Parity of Reason between their Case and ours, that can be between two Things of the same Kind.

M. From this notable Contrivance then, as well as from all the solicitous Provision we observed to be made before, it seems to follow, that the Use of the secondary Planets is only to reflect the borrowed Light of the Sun upon their Primaries.

P. That would be too rash a Supposition.

M. Pray wherein does the Rashness of it consist?

P. Our Earth performs the same Service to the Moon as the Moon does to it; or rather a great Deal more, since it reflects upon her about fifteen Times a greater Light than it receives from her: Yet no Body would say, that it was the only, or the principal Use of the Earth to reverberate the



the Sun's Light, in Order to illuminate the Moon.

M. That Assertion would be both false in Fact, and absurd in Reason. The Earth's being a habitable Globe is certainly the principal Design of it: And if it illuminates the Moon, it does that only as an accessory End, without Prejudice to the principal Use. But pray is our Earth *a Moon* to its own Moon?

P. Not to stand on the Novelty of the Expression, it is in Effect a Moon to its own Satellite: For since both Bodies are dark, or untransparent, there is the same Necessity for their reflecting the Light of the Sun on each other mutually; but the Earth reflects it much more copiously on the Moon, as being by far the greater Body. Which is manifest from bare Inspection; for a little after the Conjunction, the Part of the Moon, not yet enlightned by the Sun's Rays, becomes conspicuous to us by the Light reflected on her from the Earth.

M. I have in Truth observed it very distinctly; and from her Appearance at that Time there seems to be a good Degree
of

of Light reflected on her : For I have perceived it even before our Day-Light was quite gone.

P. You may consider what Effect the Moon-Light would have, if it became 15 or 16 Times brighter ; for such is the Moon-Light of the Moon, if I may so express it : And if you can read a small Print by our Moon-Light, what might you do there ?

M. Fifteen Times our Moon-Light would make a Kind of Day-Light, I fancy ; and we might travel, and do all Manner of Business by it, as conveniently at least as now in gloomy Weather.

P. The Earth, *Matbo*, must appear there by Night a Globe near sixteen Times larger than the Body of the Sun himself ; and therefore must throw a vast Gleam upon a Spectator in those Parts.

M. You mean, *by Night* at the Moon, and not by Night with us.

P. Your Correction is just ; that is my Meaning.

M. This must be a fine Sight surely, to see a Moon so large ! But pray, as we perceive their Moon-Light, or the Light reflected from our Globe on them ; could they

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they perceive our Moon-Light, or the Light reflected by the Moon on our Earth?

P. I do not think they could; for if their Moon-Light were but a fifteenth Part of what it is, we could hardly perceive it at this Distance.

M. I designed to have asked you almost every Time I came here, after our first Meeting, how it comes to pass that the Moon appears in such various Forms: But from what has been said just now, and at different Times before, I think I almost understand the whole Affair, without giving you farther Trouble.

P. It sometimes so happens that, by reflecting on a Subject we come to have right Notions of it, without a formal Enquiry: But pray, what are your Thoughts of the various Appearances of the Moon?

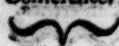
M. Being an opaque Body, and therefore necessarily reflecting the Sun's Rays, she must appear of different Forms to us, as the Hemisphere enlightened by the Sun, is more or less turned to us. Therefore in the Conjunction she is quite inconspicuous, except perhaps by appearing on the Face of the Sun in an Eclipse, as a dark Circle: In the Opposition she must appear full, for
her

her Side, to which it is then Day, is exposed to us; and between *these two* she must put on all the intermediate Appearances. I likewise easily conceive from this, why before and after the *Change*, her Horns are turned contrary Ways, still from the Sun, to wit; and her luminous Edge towards him; for her enlightened Half is then going out of, or coming into our View.

P. You are perfectly right. I had prepared for you this Figure of her different *Phases*, which can be of little other Use to you now, than to shew you that the Earth puts on all the same Variety of Appearances to her, as she does to it, but in a contrary Order.

M. Pray let me consider it in that View. — I understand it easily: When we have the new Moon, the Earth must appear at the full to her; for her dark Side being then towards us, it is Night there. As her Light increases to us, ours must decrease to her, by being carried more towards the dark Side of the Earth, and so turning her own illuminated Half to us; till she comes to the Opposition, and shines full on us, when the Earth must be quite darkened to her, unless

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unless perhaps in the Conjunction it comes over the Sun, and wholly covers him. — O right! I see now that the Earth must appear a much larger Body at the Moon, than the Sun himself, when it not only covers him wholly, but hides a great Space of the Heaven round about him. I see now more clearly what you shewed me before, That she takes a long Time to wade through the Shadow of the Earth, which is, even there, near four Times broader than herself. Well, I am delighted with all this, it is so plain, and at the same Time so agreeable too.

CXXI. *P.* A Spectator at the Moon must also enjoy a pleasing Spectacle, *Matho*, in beholding the Conversion of our Earth on its Axis in four and twenty Hours.

M. How would that appear to him?

P. By Means of this Rotation, he would be furnished with a constant Variety of Objects on his Moon, offering themselves to him successively. Our *Seas* and *Continents* would there be seen from a right Point of View, and be remarkably distinguished by a different Brightness of Colour, The Water, you know, drinking up the
Rays,

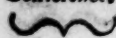


Rays, reflects but few of them comparatively; the Parts of our Globe therefore covered with that Element, must appear darker: But the scorched Plains of *Africa*, and those Countries that lie under the Equator, must have a strong Splendor.

M. This must certainly be very entertaining. *Madagascar*, *Borneo*, *Sumatra*, and the other Islands of that Tract, must make bright Spots amidst the Ocean; while the *Mediterranean*, the *Euxine*, and *Caspian* Seas, by their Darkness, set off the Lustre of the neighbouring Continents. I cannot help thinking that a View of our own Globe from such a Distance must be very agreeable. Twelve Hours must change the Scene to a Spectator at the Moon, from *Tartary* and *Asia* to the two Continents of *America*. He could not help being surprized, I fancy, with the narrow shining *Isthmus* that joins them together. He would likewise see, I suppose, Tracts of Land, which we ourselves have not yet discovered, or know only a little of their Coasts.

P. He would certainly see some Parts of our Globe which we never saw, nor perhaps ever shall see. For while the Earth, in its annual Course, turned its North and
South

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South Poles alternately to the Sun, he must perceive the *vast circumpolar Regions* quite unknown to us.

M. From all these Particulars I am satisfied, that the Earth must make an entertaining and noble Appearance at the Moon.——

P. But if you go on to consider those larger Bodies, *Saturn* and *Jupiter*, they make still an incomparably more glorious Figure to their Satellites; each of them appearing some hundred Times larger than the Sun does to us, and many thousand Times larger than the Sun appears to themselves.

M. Let me intreat you to shew me how this is.

P. As the Matter is become quite easy to you now, there is no Occasion for Intreaty. *Jupiter's* Disk is in Reality a hundred Times larger than that of the Earth; and the innermost of his Moons is not quite so far distant from him as our Moon is from us: Therefore he must appear to the innermost of his Moons a hundred Times larger than the Earth does to our Moon. But the Earth appears to our Moon near 16 Times larger than the Sun does to us;

so

So that *Jupiter* appears to the innermost of his Satellites almost 1600 Times larger than the Sun does to us.

M. This would be an inconceivably new and glorious Sight in our Parts of the System!

P. Add to this, since the Sun's Disk appears 25 Times less there than to us; *Jupiter* appears 40000 Times larger to the nearest of his Satellites than the Sun himself.

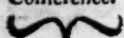
M. If I did not all along perceive the Reasons on which your Numbers are founded, I should think you only designed to indulge me in a little vain Amusement; but as it is, I am really convinced of the Truth of what you advance.

P. These Numbers and Proportions are not much over nor under the Truth; but where there was nothing that required any great Exactness it would have been needless to have affected it.

M. Pray shew me next what Appearance *Saturn* makes to his Moons?

P. *Saturn's* Disk is 64 or 65 Times larger than the Earth's: Therefore he appears to two or three of his nearest Satellites 64 Times larger than the Earth does

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to our Moon; and of Consequence, upwards of a 1000 Times bigger than the Sun appears with us. The Sun's Disk there is near a 100 Times less than here. *Saturn* therefore at the Distance of our Moon appears about 100000 Times bigger than the Sun himself does. Thus *Jupiter* and *Saturn* must appear to their Satellites, not as Moons but prodigious resplendent Orbs in the Heaven, taking up no small Space in the azure Firmament with their luminous Bodies. For on allowing *Jupiter's* Disk to appear 1600 Times larger than the Sun's to a Spectator on our Earth, you will find that his Diameter extends to more than one and twenty Degrees in the Heavens.

M. I want to see this more particularly?

P. The Sun's mean Diameter with us is about 32 Minutes, or half a Degree and two Minutes: But the Square Root of 1600 is 40; 40 Times the Sun's Diameter therefore is about 21 Degrees 20 Minutes.

M. This is plain: But pray represent the Thing to my Imagination, if you can.

P. Twenty Degrees is about the ninth Part of a Semi-circle: So that nine such Bodies

Bodies as *Jupiter* appears to his nearest Satellite must do more than reach from one Side of the Heaven to the other.

M. This gives me Satisfaction ; and I find we have no Notion of such Luminaries in our Part of the System ; for when *Jupiter* rises to his Satellites, a whole Quarter of the Firmament must seem in a Blaze of Light.

P. He appears less to the Rest of his Satellites ; but still larger than any Luminary we have a Notion of.

M. And *Saturn*, what Figure does he make to his Satellites ?

P. To the innermost of his Satellites he appears of incredible Bulk ; bigger than *Jupiter* himself to the innermost of his ; if it were worth the while to be particular on these Things : But at the Distance of our Moon his Disk is about 1024 Times larger than the Sun's to us. The Square Root of this Number is 32 nearly ; his Diameter therefore at this Distance is about 17 Degrees ; or ten and a half such Bodies as he, placed by each other's Sides, would extend over the whole Heaven, from East to West.

CXXII. *M.* All this is so new and surprising to me, *Philon*, that I cannot sufficiently express my Admiration of it. You convinced me before that the *Heaven* of *Jupiter*, or *Saturn*, was beautiful and glorious: But this View of the *Heaven* of their Satellites surpasses the Force of Imagination. For we may add to this, I presume, that every Satellite enjoys a fine Prospect of its neighbouring Moons, which must appear to it, as well as to their primary Planet.

P. It must be so, since they are reasonably supposed not to be less than our Earth: If so, when one of them is in the Opposition, or near it, and the *next inferior* ascending towards it; the higher must appear to the lower, larger than our Earth does at the Moon. But it would be endless to pursue the several Appearances they make to each other.

M. Pray what can be the Use of this Profusion of Light, thrown on these secondary Planets, even by their Primaries themselves? Or of that Light reflected on our Moon by the Earth?

P. What should the Use of it be, but that they may have Light enough to see to keep

keep to their Orbits regularly? Otherwise, revolving in those vast, pathless Spaces above, they might have missed their Way.

M. Ah, *Philon!* can you find in your Heart to joke at this Rate, on such a Subject! Let me beg of you to tell me what can be the Use of all this Light? For it is certain, that a Thing thus laid out with so much Study, and executed by such mighty Contrivance, cannot be without Design, and for no Purpose.

P. I wonder, *Matho*, you did not first ask me, What was the Use of all that Light, shed on the primary Planets by their Secondaries? Or by the Sun himself? Can this be without Design, more than the other?

M. What surprised me most was, That the primary Planets should be *Moons* to their own Moons: This made me ask the Question at first; though I find I am still as ignorant of the Question you put, and which I ought more naturally to have asked in the first Place.

P. Can the Light then shed on the greater Planets be without Design, more than that shed on the *lesser*?

M. Most undoubtedly it cannot. The *Almighty Architect* would never have made

use of such laborious Methods as we have seen, to furnish the most remote Bodies of our System with such Variety of Light, if Light had not been absolutely necessary to them.

P. And what is it in the Nature of Things, that can make Light absolutely necessary to those great Bodies lying at such a Distance from the Sun; and with which you see they are so wonderfully supplied?

M. I cannot indeed tell; but expect that you should answer this Question yourself.

P. And yet I should think that such a Question were not difficult to be answered. Tell me, What is the Use of the Light of the Moon to our Earth?

M. This I can easily answer. The Moon illuminates the darkened Part of the Earth in the Sun's Absence; she directs the Traveller in his Way, and the Sea-faring Man in his Course by Night; and divides our Time to us in a different Manner from what the Sun does.

P. Very good: But would the *Terraqueous Globe* itself (I mean the *Mountains, Fields, Rivers, Ocean,*) stand in need of Light, if it were not inhabited? Or what is it in the Nature of Things, for which
Light

Light is appointed; and to which it answers? To Eyes, or to Ears? You see we stand in need of Light in our Houses; but could there be any Necessity for these, if the Houses were uninhabited; if no Body dwelt in them?

M. It is enough, *Philon*; pardon my want of Thought. I ought to have been upon my Guard, when you began with your ironical Way of Joking. You mean, that all the other Planets, as well as our Earth, are habitable Globes, and the Residence of such to whom the Light of the Sun may be serviceable; or, to speak more justly, to whom it is altogether necessary.

CXXIII. *P.* Why was a Sun necessary at all in the System, *Matbo*, if not upon this Account? Why might it not have been a dark, a torpid, and a motionless Abyss? Or why was the Frame of Nature built at all? — These are Questions we should know how to answer, if we are capable of answering any thing; if we know whether we were made by *Chance*, or a *designing Cause*. Every body will own that the System required a Sun, regular Motions and the present Contrivances; because it was to be

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inhabited. — Right : But was it to have a Sun, and these Conveniencies, that only the hundredth Part of it, nay that less than the hundredth Part of it, should be inhabited? Was it to have these Contrivances, that it might be uninhabited even where they seem to have been most studied? For, if we may compare the Works of the Creator among themselves, the Contrivances for illuminating the superior Planets are, without Controversy, extremely more studied than in the lower Parts of the System. Call to Mind again the Heavens of *Jupiter* and *Saturn*, what bright Parts of the Universe those are; tho' so far removed from the Sun. These Bodies, you owned, appear to each other vast Globes of Light, far exceeding the Notion we have of *celestial Luminaries*. If we suppose a Spectator brought from thence to our Regions, he must think he were conveyed to a dull and languishing Part of Nature.

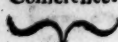
M. You have shewn me that Particular to Satisfaction : But I ought to have foreseen this Consequence long ago, when I observed such various and artful Provision made for throwing Light on all the Parts of the planetary World; when I beheld the Planets placed, not one without another, but five or six of them

them so disposed at the same Distance from the Sun, that they might all enjoy his Light equally, and reflect it likewise on each other mutually. This is such an expressive Artifice, as is not easy to be mistaken: Otherwise what Difference would there have been, whether the Planets had been placed far from, or near the Sun; were they not to have been replenished with Inhabitants, who might perceive the Advantage of the Light? Or what needless Work had it been, so carefully to provide the Comforts of *Living Beings* for Things void of Life?

P. This Consequence seems to be implied, *Matho*, from the very Time we understand the Sun to be such a vast Body, merely upon the Account of the Planets. He was to keep them near him by his Attraction, and to cherish them by his Heat and Light. But to cherish what? Some mighty Globes of Marble, for Instance, some huge Masses of dead Matter! No Reason at all would be better than this.

M. I confess I ought to have considered the Work in this View, when first I understood that the Planets were made to revolve about the Sun by such wonderful Power; that they might move without changing Distance

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stance from their Center of Heat and Light: And when I first saw that they rolled round on their Axes, that they might enjoy the Light and Shade alternately. No Eyes could bear a perpetual Splendor. But above all, I ought to have foreseen this Design of the Work, when I saw Planets revolving about other Planets, and those revolving about the Center of Heat and Light! This could not be a mere Flourish of Skill in the *Almighty Architect*; an ambitious affected Ornament, that served only to shew what he could do when he had a Mind.

P. You are grown a powerful Orator for this Side of the Question, all of a sudden, *Mattho*.

M. I am serious in what I say, and do not talk thus out of an Affectation to be thought to understand a Thing, before I see it. When I reflect on all we have said from the Beginning, it appears to me consistent in this Sense; but without this it seems scarce to have a Meaning: Every thing indeed confirms it, and nothing, so far as I know, makes against it. For why should our Earth alone of all the Planets be furnished with Inhabitants; since it is neither the greatest, nor the innermost, nor the outermost, nor the

the best furnished with Light, or with Variety of it, to receive them: I say, why should it of all the Planets be graced with Inhabitants, while others, either larger, or nearer the Source of Heat and Light, are left empty and desolate? It vanishes long before we come to *Jupiter* or *Saturn*, the least of whose Satellites are probably as large. It is placed, suppose, at 21000 of its own Semi-diameters from the Sun: What is the Meaning then of *Jupiter*, a much larger Body, placed at 5 times that Distance? Or of *Saturn* placed at near 10 times that Distance? Or of *Venus* placed at 1500 such Diameters from him? Could not this Earth have rolled round the Sun, and been inhabited, unless it had been attended with those larger Bodies, rolling likewise round him without Inhabitants?

M. I think therefore, *Philon*, we should never look to the Heavens, and those mighty Bodies that roll round with us; nor consider that their Motions are governed by the same common Laws, nor suffer our Thoughts to rise above the Surface on which we tread; unless we come into this Opinion: For it appears to be *that*, which can only solve a thousand Doubts in our Mind, and free us from

from a thousand Absurdities, which we must otherwise entertain concerning the *great Architect* of the World.

P. There seems in Truth to be no Medium, between remaining quite ignorant of all the Miracles of Power, and Wisdom, which appear in the Heavens, and coming into this Notion: And on this Account it was, that Men came into it, as soon as they began to compare this Earth with the other great Bodies in Nature, and found that it was but as a Point in Comparifon of the Universe. But

CXXIV. Since you have fo little Doubt of the primary Planets being habitable, what do you think must be the Ufe, or the Design, of that more copious Light reflected on the Moon by our Earth; or by thofe larger Bodies *Jupiter*, and *Saturn*, on their Secondaries?

M. I fhall not readily forget thefe laft; and as more ample Provision hath been made for them, than for the primary Planets themfelves; they cannot be idle *Phænomena* in the Sky, to amufe — I know not what Beings, if none are there: But the different Abodes rather of fome fort of living Creatures:

tures: For thus the Convenience of *more* is consulted, as I remember you observed some Time ago.

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P. Certainly the System is then of more Use; nor can it be construed a Blunder, or Misunderstanding of the Design, if the Works of the *Author of Nature* are not idle, or employed to small Purpose.

M. It is rather true on the contrary that, the more useful they are, the more skillful they must be accounted. *A large Design, with small Convenience* shews that the Artist was not Master of his Business.

P. You express the Case with Propriety. It might be said that our Seas are large; but we have seen that they are referred to the Uses of Habitation; and besides they are the Nursery and Seat of numberless Species of living Creatures: Our Mountains are wild; but they are notwithstanding a continued Scene of Vegetation and Life, and not useless Deformities on the Face of the Globe.

M. And by a Parity of Reason, these secondary Planets certainly answer a more noble End, if they are equally the Seats of living Beings, than if they only reflected the Light emptily, on other empty Globes.

Without

Without this we cannot imagine to what Purpose such vast Spheres should bandy the Sun's Splendor from one to another, and keep up an *eternal Dance*, unperceived by any Creature, unless perhaps by a few studious Persons here on Earth, peeping through a Telescope. I cannot bear to think that such wonderful Sightings should have been so far removed from us; if there were none else to admire them.

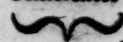
P. The Thought indeed shocks common Sense. But it is likewise of Consequence in this Affair, *Matho*, to consider that on the Surface of the Moon (the nearest of those Bodies to us) as seen through the Telescope, frequent *Mountains*, higher than ours, *Rocks*, *Lakes*, and Seas are discovered; all which shew a Planet not unfit for Habitation, but disposed like to our Earth.

M. Something like this is perceived even by the naked Eye.

P. Here is a pretty exact Figure of the Moon, *Matho*, as observed through the Telescope.

M. Pray let me look at it. There is indeed a great Inequality on her Surface here, and Variety of Light and Shade; for some Parts are very dark, and others resplendent.

I don't



I don't know whether there be such a Difference of Appearances even on the Surface of our Earth.

P. You cannot, unless you were to see it from the Moon.

M. What ragged and broken Places are these, on the Edges of these lesser Figures?

P. Consider how large these Objects must be in themselves, when they lie at near 24000 Miles Distance from us! These are *Rocks, Mountains* and *hollow Vallies*, which become thus conspicuous in certain Positions of the Moon, with respect to the Light of the Sun: The Tops of these Mountains appear thus by the Rays of the Sun striking on them, before the Light hath reached those Parts of the Moon's Surface, where they are situated.

M. Surely the Use of these *Inequalities* and *deep Shades* that appear, cannot be to reflect the Light on us: Such large Heights and Declivities seem rather fitted for the Descent of Waters, and the Uses of Vegetation.

P. What you observe seems of great Weight: No body can be so fanciful as to imagine that those *dark Tracks*, and *deep Shades* are designed for the Reflexion of the



the Sun's Rays. But it is farther observed, that these Shadows seen on the Surface of the Moon are contracted, as those Parts of her Disk are more turned to the Sun: Just as the Shadows of our Mountains become shorter, as the Sun rises higher; and quite disappear in the Height of the Day: Which shews that it is but a secondary Use of this Planet to reflect the Sun's Light back on the Earth. If that had been the only, or the principal Use of the Moon, she must have had a certain equable Roughness of Surface, like an unpolished Block of white Marble, for dispersing the Sun's Rays every way: But no Rifings, or Inequalities, like Rocks or Mountains. But the Author of Nature, who is the *first Optician*, and knew what Effect her present Surface would have at the Earth, hath given her a Mixture of the one and the other, to answer different Ends. And hence it is that we receive great Assistance even from her reflected Light: And she receives greater from our Earth, though made unequal by Mountains and Vallies. In short, the most diligent Observers of this Planet conclude, that our Earth seen there would make just such an Appearance to the Eye, (though

(though much larger) as the Moon does to us here.

M. This Point seems to be out of Doubt, unless we would insist on Proofs which cannot be had, from the Nature of the Case: For, since our Earth is an habitable Globe, and at the same Time serves as a Moon, there is certainly equal Reason for concluding, that the Globe, which serves us for a Moon, should be habitable too. — I remember you said before, that the *Arch*, which surrounds the Body of *Saturn*, seemed not wholly designed for reflecting the Light on the interior Planet; since it keeps off as much at one Season, as it reflects at another: Now pray what may your Thoughts be of this singular Piece of divine Workmanship?

P. It is more easy (as I said then) to tell you what I do not think of it, than to form any consistent Thought about it. I do not think it the Ruins of an exterior Crust, the rest of which hath fallen down upon the Body of *Saturn*. The Dilapidation of a Planet hath to me a strange Sound; nor are Ruins wont to be so regular: Though even that would make it originally designed for Habitation. Nor can I think it is a fluid Body. It must then indeed have a swift Rotation.

tation on its Axis, to give every Part of it a centrifugal Force equal to its Gravity, and hinder it from falling down, the Time of which might easily be assigned: But I do not see why it should then be flat and broad, with the Edge towards us; it ought rather, I think, to be of a round or cylindrical Form. So that it appears more probably to be solid.

M. You seem inclined, I think, to suppose that this *pendulous Structure* may even be habitable.

P. Every Body in Nature, *Matbo*, is pendulous, tho' in different Circumstances from it. There is no Absurdity in supposing it may be habitable, and serve at the same Time for some great Purpose to the Planet it surrounds, as well as receive Advantage from it: But the safer Way is to own, that it demands our Admiration, while it is beyond our Reach to discover the Use for which it was thus contrived.

M. Leaving this Body therefore as we found it; this I think seems to me beyond rational Doubt, that all the Planets, primary as well as secondary, are the Abodes of some sort of Inhabitants or other.

CXXV. P. Consider then in the next Place, *Matbo*, whether a skilful Artist could design that which is of greater Dignity, only for the sake of the inferior Part of his Work?

M. Here, *Philon*, I fancy I guess what you intend by this Question; and the Answer is obvious: A skilful Artist could neither design such a Blunder; nor could a fair Enquirer in the present Case imagine, that *Man* was made for the sake of the Brutes, nor the inferior Animals for the sake of the Vegetables, nor the yearly Production of Vegetables for the Relief and Comfort of the Soil on which they grow. This would be to turn the Bottom upward, and invert the Order of Things. I have not forgot what you shewed me concerning the *rising Scale* of created Beings. This *Gradation* is the Voice of Nature, as well as of Reason, and confirmed by constant Observation of the different Species of Things on and about our Earth. The Relation and Aptitude of one Thing to another, where the *Unity of Design* appears through an infinite Variety of Particulars, always rises upward.

P. You resume the Substance of what we then said, in a just and expressive Manner.

ner. — For whose sake then, tell me, was this Earth formed, furnished out, and placed to revolve among the rest of the Planets; for the sake of the rational, irrational, or vegetating Beings on it?

M. This Question is so plain, that I know you will hardly expect I should give you a direct Answer: But you mean that the other Planets, as well secondary as primary (which appears now to be rather a nominal Distinction, than to imply any real Difference of their Use and Nature) could not have been made on the Account of brute Animals, which can neither conceive the Beauty of the Work, nor acknowledge the Benevolence of the Creator, nor have their Nature improved by the Power and Wisdom displayed in the Order and Variety of the Parts.

P. Undoubtedly, *Matho*, the same Reason holds, and is indeed stronger with respect to the rest of the Planets, than to our Earth. For if it would have been unsuitable to have peopled a lesser Planet only with brute Beasts, it had been still more absurd to have made the Systems of *Saturn* and *Jupiter*, only for the sake of irrational Animals. Wherefore a nobler Guest was to be placed in those magnificent Globes; who, though perhaps not resembling

resembling us in all Particulars, may nevertheless be endued with the same rational Nature, and that possibly in greater Perfection, in Proportion to the Dignity of those nobler Mansions. — It is strangely inconsistent with Reason, to imagine this vast Structure of the Universe to have been raised up in immense Space only to be the Seat of eternal Silence and Solitude; the starry Worlds on high unfolded, the harmonious Motions of the Planets contrived, and all adorned with amazing Splendor and Brightness, only that wild Beasts might have a more convenient Retreat!

M. Ah, *Philon!* name not such a grievous Absurdity! It shocks Nature, and affronts the *Infinite Reason?*

P. Wherefore, I say, a *more divine Nature* than such Kind of Beings, was wanting to complete the Design; a Nature sanctified with Reason, aspiring after the endless Improvement of the rational Faculties, searching into the necessary and eternal Reasons of Things, itself desirous of, and designed for Eternity. For Reason most plainly denies that a rational Nature should ever die.

M. You carry me irresistibly along with the Strength and Pleasure of the Argument.

It must be allowed that God, who is the *Infinite Reason*, cannot but delight in rational Works; nor can he be the Creator of other Things, except so far as they are subservient to these. It is thus the Government of Reason is known from the Temerity of Chance.

P. Your Inference is solid, and of the last Importance: And from thence it will follow, that he could only have been the Creator of inert Matter, or of a sensitive and irrational Nature, so far as they regard something higher. And wherever that, which was made for the sake of another, is, there that, for whose sake it was made, must be.

M. How vain and peevish is *Man*, who makes himself the only Favourite of Heaven, and claims to himself alone the Care of Omnipotence! as if the Kindness shewn him supposed a Neglect of all other Things; or, as if he were injured, unless the Universe were an *infinite Waste* to please him. How much better were it, as Modesty requires, to acknowledge the other Bodies in the Universe equally dignified by *Reason*, with this Seat of ours!

P. I believe, *Matho*, you have said more than you are aware of; the Universe must

be a *Waste* almost infinite indeed, if the Opinion of the greatest Philosophers, founded on the Nature of Things, may be depended on in this Case.

M. Pray what is their Opinion? I should be glad, if what seems so agreeable to Reason has also the Authority of better Judges. And it must, I think, appear reasonable to every body, that the living and rational Creation should be as extensive, as the dead and inanimate Part of it; since it is undeniable, that the latter was made for the former. But to imagine that, while the material Universe is almost boundless, the rational Creation is so confined and narrow a Thing, that a Ship might sail round it in a few Months, is, I'm afraid, to measure the Works of Omnipotence by our narrow Prejudices. — But pray go on to acquaint me with the Opinion of the *Learned* on this Head.

CXXVI. P. You observed long since, if the Sun were removed always farther and farther from a Spectator, or the Spectator from him, that he must still seem less and less, till at length he should appear but of the Bigness of a larger Star, or even of a lesser.

N 4

M. — And

M. — And that at last he would quite disappear; because from the Increase of the Distance the greatest Bodies must at length escape the Sight. Nor, I presume, can any other Reason be assigned, except the Vastness of the Distance, why many Stars, which cannot be discerned with the naked Eye, become perceptible through the Telescope. And even those probably are not the most distant; for the Telescope, as well as the Eye, must have its Limits.

P. Surely it must. Could that Invention be brought to the last Degree of Perfection, it would, no Doubt, discover to us Stars hitherto imperceptible; since the more perfect any Instrument of this Sort is, the more of those celestial Bodies it brings within our View. It is surprising what Numbers of them have been discerned by this Means, in a Space where we see but very few, or none at all. In the *Pleiades* alone, where we can discover but six or seven, near two hundred have been reckoned.

M. From all this then it naturally follows, that the Distance may be so great that the Sun himself could not be conspicuous from thence.

P. Or

P. Or any Body equal to the Sun in Magnitude and Splendor.

M. That is but the same Case.

P. Now the Distance of the fixed Stars from us is so vast, that the Distance of the Earth from the Sun is but as a Point in Comparison of it.

M. This you mentioned in our third Conference, and I have thought of it frequently since ; for it raised my Admiration and Curiosity : Please therefore now to shew me what Ground there is for that Assertion.

P. You must first call to Mind that the Diameter of the *Magnus Orbis* (as it is called) or the Earth's annual Orbit, is upwards of forty thousand Times the Semidiameter of the Earth itself, according to the common Supposition of the Sun's Distance ; that is, upwards of an hundred and sixty millions of Miles.

M. Could you not give me some sensible Representation of this Distance, as you did of the Sun's Magnitude ? For bare Numbers do not strike the Imagination.

P. I cannot indeed : All our Measures, and sensible Images are swallowed up here, without being known : You see it is more
than

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than forty thousand Times the Semi-diameter of the Earth itself, which is our greatest Measure. Even, the Moon's Orbit, which helped you to conceive the Magnitude of the Sun, could not much assist your Imagination in this Case.

M. Well, go on.

P. Now when the Earth is in the opposite Parts of its annual Course, or hath really advanced a hundred and sixty millions of Miles nearer some of the fixed Stars, and hath left others of them so much behind, it seems not to have changed its Place with Respect to them, nor they to have altered their Situation with Respect to each other in the least: Which could not be if this Diameter of the *Magnus Orbis* bore any assignable Proportion to its Distance from the fixed Stars.

M. Let me consider this a little. — If I should travel a hundred and sixty thousand Miles straight forward every Year, for a thousand Years together, and yet never perceive myself draw nearer certain immoveable Bodies that were before my Face, nor farther from others that I see left behind my Back; and if one particular Body, in all that long Journey, should still appear
with

with the same Degree of Elevation above my Head ; — I see plainly the Consequence : Those Bodies must indeed be at an inconceivable Distance from me ; and the Space I had travelled over must bear no Proportion to their Distance ; otherwise they would seem to have changed their Situation among themselves ; as the Objects in a large plain are thrown into a different Order, while I travel through it.

P. You have formed to yourself an Idea of this to better Purpose than I could have done : Only this is no Fiction ; you are really carried thus far, not indeed once in a thousand Years, but twice in one Year. For in Effect you are about the 10th of June a 1000 Times a 160000 Miles farther from the Northern Parts of the Heaven than you were the *December* before : And yet you perceive your Situation with Respect to them no Ways changed.

M. This then helps me to understand that *immense Triangle* you supposed drawn, of which this Diameter of the *Magnus Orbis* was the Base ; and the two Sides meeting in the Pole of the Heavens, were yet with Respect to our Perception parallel. Whence we inferred that the Base was but

as

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as a Point in Comparison of the Sides. The one Argument illustrates the other: And from hence I perceive we rightly inferred the Parallelism of the Axis of the Earth to itself, in all its annual Course; to which chiefly we owe our Diversity of Seasons.

CXXVII. *P.* From this Account then how large Bodies, do you think, must the fixed Stars be, which are thus conspicuous at such a prodigious Distance?

M. Vast Globes certainly; not less perhaps than the Sun himself.

P. There is neither *perhaps* nor *peradventure* in the Case, *Matbo*, for it can be shewn by irrefragable Arguments, that were the Sun at such an immense Distance, he would not appear larger than one of those Stars: Nay, were he not a luminous Globe, he could not be seen there at all. But those Bodies are conspicuous at greater Distances, than are mensurable by the Laws of Opticks. And hence it is that the most judicious Astronomers have rightly concluded, that the *fixed Stars* are prodigious luminous Bodies, equal to the Sun in Bigness;

ness; or that they are themselves indeed so many Suns *.

M. I said *perhaps*, not that I doubted; for this Conclusion seems to follow from what was said just now, *viz.* That the whole Diameter of the *Magnus Orbis* is but as a Point in respect of their Distance. But why did you say, That they are seen farther than the Laws of Opticks reach to?

P. When they are seen through a Telescope which magnifies above a hundred Times, they do not appear bigger than at present; or rather they appear less, but better defined; the tremulous Scintillation, or Sparkling, being thus cut off. Whence it is inferred that, were the Distance between them and us but one 99th Part of what

* Hinc patet Systema Planetarum circumsolarium, è fixa spectatum, visum prorsus fugere, & in idem punctum lucidum confundi cum Sole, cujus Diameter insensibilis fiet, si distinctè spectetur & orbatus Capillitio, quali fixæ Terricolis cinctæ videntur. — Ideoque vicissim Planetæ circa Soles istos [*fixas*, scil.] rotati Observationem nostram effugiunt penitus. Dubium non est quin, oculo in fixa aliqua (aut Planeta circa illam revoluta) posito, reliquarum circumcirca fixarum Ordo & Constellationum Figuræ diversa sint prorsus ab illis, quæ nos spectamus; quippe cui Sol noster Stella fixa videtur. *Gregor. Astronom. Lib. 6. Prop. 7. Coroll.*

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it is, we should perceive them little bigger than we do at present. And since the Breadth or Diameter of Objects decreases, as their Distance from the Eye increases; the fixed Stars (according to the Rules of Opticks) must be quite extinguished, long before the Distance were increased to 99 Times as much. Whence, were the Sun at the Distance of the fixed Stars, he would appear only as a luminous Point, without Breadth; and were he not luminous, he could not appear at such a Distance at all.

M. I had no Difficulty on this Head before; but what you have now added gives me still more Satisfaction. And since in the Immensity of Space the greatest luminous Bodies must at last disappear, their different apparent Magnitudes may be owing to their different Distances; allowing they were all equal among themselves.

P. On that Supposition another Reason cannot be assigned.

M. This Boundlessness of the material Universe distresses the Imagination; and is literally inconceivable! —

P. If then the fixed Stars are Suns equal to ours, which can only be denied by shutting our Eyes to these Reasons; Pray
for

for what Purpose shall we say they were created? That they might twinkle to us in a Winter-Evening through the infinite Space?

M. I foresee what you aim at; but go on: Their twinkling to us, whatever Pleasure it may give us, cannot be the principal Design of the Creator in forming them.

P. If they were solely designed for our Use, why are they so far removed from us as that we should not have the full Use of them? — Why are they *so many*, when fewer; or such *great Bodies*, when lesser Lights placed nearer to us, might have been more useful?

M. Do not mention such an Absurdity; no Body will so much as pretend it. What Use could this little Globe have had for such a Number of Suns? Or how could it have borne them nearer? Shades and Darkness are as necessary to our State as Light itself. —

P. If then those Bodies are luminous Globes, equal to the Sun in Splendor and Magnitude, can they serve for a less noble Purpose, or be of less Use in the Creation, than the Sun himself?

M. Equal

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M. Equal Bodies must serve for equal Purposes; unless we would suppose that the *Author of Nature* wrought accurately only in our System, and loosely in all Parts of the Universe besides. Which I'm afraid is the general Prejudice, in this as well as in other Cases. —

P. Do you think that to an Eye placed at the Distance of *Sirius*, or *Arcturus*, where our Sun would appear but as a luminous Point, the solar Planets could be discerned?

M. No; They must be confounded with that Point, as much (and more) as the inferior Planets, *Mercury* and *Venus*, are confounded with the solar Rays, at the Distance but of *Jupiter* or *Saturn*. — From all this you infer (nor do I see what can be said against it) That the *fixed Stars* have each their System of Planets, which cannot be discerned by us at this immense Distance; and that they shine to the Inhabitants of those Regions.

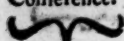
P. Perhaps they shine to none?

M. Yes, if Light doth not answer to Eyes; or rather if it answers to nothing.

P. If then, they shine to any Beings, can we imagine that they shine for the Sake
of

of those who do not perceive the hundredth Part of them, without the Help of a Telescope, or even perhaps with the Assistance of that Invention?

M. That would be notably repugnant, to imagine they shine for those who do not see them. Wherefore, I say, I would not have you so much as suppose that such Use of them is pretended; since no Body, I believe, will imagine it. I readily come into your Sentiments: For, as was observ'd before, we must either not think upon this Subject at all, but forget that there are such Bodies in Nature; or if we reflect upon them otherwise than Children do, (who look upon the Stars as so many bright Studs, with which the vaulted Roof of Heaven is adorned) we must come into this Opinion. The Inhabitants of those Parts and we seem to be much in the same Condition. To a Spectator placed there our Sun must appear as a fixed Star, and the solar Planets be quite absorbed by the Immensity of the Distance: Yet it would not follow, that there was no such Globe as our Earth, and that no living Being existed near *that fixed Star*. In short, this Point can only be determined in the Nature



of Things, by the Principles of Reason: And to reject it because it cannot be ascertained by Eye-Sight, or by travelling into those Parts, seems equal to picking a Quarrel with Reason itself.

CXXVIII. *P.* If, *Matbo*, any other Use of Light could be imagined, than to answer the Purposes of Eyes and Vision, or if Eyes could belong to any other than a corporeal Nature, I should not suppose that any Species of animal Creatures resided in those Parts: Or if it could be supposed that by far the greatest Part of the Universe was to fall to the Share of brute Creatures (while a Point only was allotted for the Habitation of rational Beings, which can hardly be discerned among the other Bodies in the Creation;) I should suspect that only brute and sensitive Animals might inhabit the wide Expanse of material Nature. But since these Suppositions are inconsistent with Reason, and inferior Creatures were only designed for the Sake of nobler Beings, I am forced into this Opinion whether I will or not.

M. And I, on the contrary, come into it with Pleasure. I remember with what
Surprize

Surprize I first heard of the *Antipodes*; Inhabitants, as I thought, with their Heads hanging downward: But now I am sensible what a Void there must have been, had not our Globe been habitable quite round. It would then have served but just for half the Use it serves for now.

P. You do not know, *Matbo*, that some Centuries ago it was reckoned absurd, and little less than impious, to suppose that there were Antipodes, or Inhabitants on the opposite Part of our own Globe. This Narrowness of Thought is now laughed at as an idle Prejudice of ignorant Antiquity: But once it was a serious Affair. So difficult is it to get the better of Prejudices that have once taken Root in our Minds!

M. So much the earlier therefore they ought to be corrected. But in the present Case, I shall for the future contemplate the Face of the Heavens in the Night Time with more Delight, while I consider that all above me is not a wild Solitude, designed only to fatigue the Eye, and amuse us puny Mortals; but that rational Beings inhabit those Regions, and admire with us the Wisdom of the common Creator, displayed in their different Views of Nature: And

while I reflect, that we have not passed the Bounds of the rational Creation, when without the narrow Limits of our own System.

P. You have seen how narrow the Limits of the System are, compared with the whole Creation : So that whatever Reason shews us that the Rest of the Bodies in the solar Regions are not unfinished or uninhabited Seats, must likewise shew us that the other Systems in the Universe (which bear an incomparably greater Proportion to them than they do to our Earth) cannot be an immense Desert, nor be without Spectators of what is done there by the *Almighty Architect*.

M. I understand : The Reason becomes still stronger the higher we ascend.

P. If once we go beyond the Surface of this Globe on which we tread, we can stop no where ; nor rebate the Force of the Reason, which still becomes stronger, till we acknowledge the material Creation habitable throughout. Hence we must suppose that only a Point of the Universe is habitable ; or that the whole Universe is habitable. The Argument will always return upon us, *Wherever that which was made*

made for the Sake of a nobler Nature is, there the nobler Nature for whose Sake it was made must be.

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M. As was said in a like Case before, it is probable the contrary Opinion first prevailed, because Men believed that the Earth was the greatest Body in Nature; that it occupied the Center of the Universe; that all Things else were created for its Sake; and that the Heavens consisted of solid Orbs, which whirled round our Globe in four and twenty Hours.

P. Let us only add to this, that an *universal upward and downward* was believed to reach through all the material World, respecting only this Earth; and I believe we have all the Prejudices on which the contrary Opinion was founded. So that whatever removes this Heap of vulgar Mistakes from Philosophy, and shews that the Earth revolves among the other Planets, and that its diurnal Rotation supersedes the rapid Motion of the Spheres; shews at the same Time the Reasonableness of this Opinion.

M. We ought therefore, I think, to come into it, in Consequence of having thrown off those Prejudices; unless we

would be thought to have reformed our Philosophy by halves only. And I am persuaded, if we would but reflect that there is a *Downward* to other Bodies in Nature, as well as to our Earth; that alone would reconcile us to their being habitable Globes; But wherever a Body revolves about another as a Center, that shews a *Downward*. The Moon rolls about our Earth; from *thence* therefore to us is downward; The Moons of *Jupiter* and *Saturn* roll about those Planets; whence there is a Tendency down to these also.

P. And that a much stronger Tendency than to this Globe.—In fine, *Mathe* (for we must have done) it is of Importance to consider here, that the Deity might, according to his Good-Pleasure, have created more or fewer Worlds; But to have applied them when created to no Purpose, or to have replenished one little Globe with rational Inhabitants, and left innumerable others empty and useless, is the perfect reverse of Art and Contrivance,

M. That could only have been the Effect of Power undirected by Wisdom.

P. And then upon Reflection you will find one Thing extremely remarkable. The Mind

Mind of Man itself only rests satisfied with those Effects of Almighty Power, the Greatness of which it can neither conceive nor search out; and this whether we consider the *Grandeur*, the *Number*, or the *Subtilty* of his Works. For as long as it can fathom something farther, so long it conceives Omnipotence circumscribed: And since this is a repugnant Thought, it rests only satisfied when it can explore no Limits to Power, and Contrivance. And in this singular View the Power of the Deity offers itself to be revered and adored by us! It was observed before, that we can see a little about *the Middle*; but could we reach to either of *the Extremes*, we should find ourselves disappointed. The Mind would sit down discontented, having nothing more to look for. As this is a Mark of Eternity (shall I call it?) in the Mind of Man; so what Richness of Power is it, that we can neither find out the Beginning, nor the End, nor the Extent, of the Works of God!

M. What a noble View then of the material Creation have we from thence!

P. A quite different one certainly from that, which represents the celestial Orbs in-



closing our Earth, as the *Shell* does the Kernel.

M. Name not that Disgrace of Philosophy. Here the boundless celestial Spaces, from East to West, from the North to the declining South, are appointed for Life and Habitation; the *Seats* of Reason and (if I durst so say) Humanity. I descry Worlds without Worlds; Suns and Systems, till the Imagination is wearied.

P. And there *Nature* and *Creation* begin anew, till the Creature sinks in endeavouring to grasp the Works of the Creator.

M. This after all is a Work, this only a World worthy of the *Omnipotent Architect*, immensely Good, immensely Powerful!

CXXIX. *P.* But does not the Consideration of these Things give you some Concern, *Matbo*, lest the Deity should neglect you, having such a Multiplicity of other more important Affairs to look after?

M. This, as I observed before, *Philon*, can give me no Concern; while I reflect and feel, that the constant Action of the Deity a thousand Ways supports me. While I look or walk, while I speak or think, my corporeal Frame is preserved by innumerable concurring

concurring Actions of Cohesion, Gravity, Repulse, in every Part of my Body: Nay while I sleep or breathe, and have not my Thoughts at my own Command, the Deity powerfully supports me. But why should the Multiplicity of Affairs perplex the Deity? That only belongs to a limited Power. Did we see from the strongest Reasons that his Power, Wisdom, and Goodness are infinite, only to forget the Consequences of that Conclusion, when we had Occasion to refer to them?

P. It is surely as you say, *Matho*; every Pulse of the Artery, every Draught of Air we fetch, every Motion and Change of material Parts we feel in our Bodies, is a Pledge of the present Power and Kindness of the Creator; so that he is no less powerful and good to us, than if he were powerful and good to us alone, and to no other Beings. And then, as you observe farther, since it is the Property only of limited Power and Knowledge, to be perplexed and confused with the Multitude of Business, it would be foolish enough to fancy that the Deity might be over-powered in exerting his Power, or confused with the Extent of his own Knowledge.

M. Such

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M. Such Notions are inconsistent, and destroy themselves. And from thence we may with Pleasure infer, that we cannot consider the Multiplicity of the Works of the Deity, as the Effect of his infinite Power; but we must at the same Time be sensible of our own Security, how small a Part of them soever we may be.

P. So little inconsistent indeed are these two, that the Care for *the whole* consists in a minute and constant Support of *all the Parts*.

M. But pray, *Philon*, inform me here, how our Bodies are constantly preserved from the crushing Weight of the incumbent Atmosphere, by the Particles of Air in all their Parts? This you mentioned in great Hurry just at our last parting.

P. I will not recommend that Notion to you (though it is the only thing that gives me Satisfaction in this Particular) and it was for that Reason I mentioned it in such Haste: However I shall tell you in few Words what seems right to me; and you may choose, or reject it afterwards, as it shall appear reasonable to you on Reflection. No human Force or Industry can bring the Particles of Air into Contact; hence the
Spring

Spring or repulsive Force of the least Particle must be of itself sufficient to bear off the Weight of the whole.

M. I conceive a Quantity of Air then, as consisting of a Number of small Atoms, which suddenly start from one another, if at any Time they have been squeezed into less Room.

P. You are right; when the Air is strongly compressed, the Effort it makes to restore itself is incredible. Heat increases the repellent Force of the Air, and generates no small Quantity of it, as we may see by the Vapour and Steam forced out from all combustible Bodies while they burn: From burning Gun-powder especially great Quantities of Air are produced. From this Increase of the Spring of the Air by Heat, and the new Quantities of it produced, proceeds that fierce Explosion, which throws out the Bomb, or Cannon-ball with such Violence.

M. In this manner may *Ætna*, or *Vesuvius*, rage by the same Force.

P. And the Earth itself tremble too.— Now since Air may be generated from other Substances, by Heat, or by Fermentation, it seems perfectly needless to enquire solicitously how it can get into all the Parts of

MATHO: or, The

our Bodies by external Conveyance ; or to place the whole Strefs of the Question in the formal manner how that can be effected. It was constantly in all Parts of them, as being generated inwardly ; and the Quantity of it, sufficient to balance the Weight of the external Atmosphere, can never be wanting. Nothing else could save us from being crushed, unless we should call in the Help of a constant Miracle. This itself, I allow, is a constant Miracle : But then it is in the Course of Nature, and according to the Methods which we reckon commonly mechanical.

M. I understand pretty well what you say ; but something still sticks with me for want of farther Information. What is the Weight with which you reckon the Atmosphere constantly presses us ?

P. Since it presses us on all Sides, the Weight must be as the Surface it acts against. One Man may support a Weight as ten Tun, and another fifteen, or even twenty. But if a Man were squeezed by half of this on one Side, it would press him to Death in a Moment.

M. Why could not the internal Air in all Parts of his Body balance this Weight ?

P. Because

P. Because it would have nothing to act against on the other Side. The Weight of the internal Air may be but a few Grains : This could never balance a Weight of ten or fifteen Tuns. But as soon as the Atmosphere acts on the other Side, the internal Air by its repulsive Power defends itself in the Middle, and keeps off the Pressure on each Side ; so that we feel the Pressure no more than if there were none.

M. I begin now to have a Notion of it. I fancied that the Pressure on the one Side might balance the pressure on the other ; or that the external Air formed a sort of *hollow Case*, as it were, round the Body, which supported, or kept off the Weight. But now I see the repellent Force of the Particles must push them to act on all Sides.

P. While we blow up *Soap-Bubbles*, which was mentioned before, into a spherical Figure, we are not to imagine that the external Air forms itself into a hollow Sphere, which suspends the Weight of the Atmosphere from acting on the Sides of the included Bubble ; though a spherical Figure be allowed to be the most advantageous for such a Purpose. If it were so, consider what prodigious Force it would require to
blow

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blow up the Bubble, and thereby to form this hollow Sphere, or suspend the Pressure of the Atmosphere on all Sides of it. This shews us that it is the internal, or included Air, which (by its Spring) performs this Effect. And if this be so in a spherical Figure, it must be more so in any other Figure less regular.

M. You have entirely satisfied me on this Head, *Philon*. When I reflect on the various Shapes of all sorts of Animals, and their constant Change of Figure while they move, the external Air cannot constantly throw itself into *hollow Cases* to keep off the Pressure of the Atmosphere from their Bodies. — But what was it you said, when we parted, of People that dive under Water?

P. The Water must press them on all Sides, and that in Proportion to the Depth they dive to; nor can any thing defend them, in my Judgment, but the Spring of the Particles of Air in all Parts of their Bodies: For the Water being an unelastick Fluid, or having no repellent Force between its Particles, is less fit than the Air to form itself into such ambient Figures, as might defend their Bodies from the Pressure. If this were so,

so, it must defend them in all Depths alike: But the farther they go down, they feel the greater Pain in their Heads, Eyes, and Arms; according as the Spring of the internal Air is more over-powered.

M. Why do you say that no human Force could bring the Particles of Air into Contact?

P. In the greatest Degree of Compression Men can give the Air, Bodies move up and down in it without a Resistance sensibly greater than ordinary. If the Particles of Air could be brought into Contact, it must probably be as dense, and therefore as heavy as Water.

M. I remember indeed what you said, of breathing a fluid as dense as Water, when you first mentioned to me a *repulsive Force*.

P. Now I hope we have done.

M. We must rather return back to our Subject concerning the Planets; for

CXXX. There are still two or three Particulars I should be glad to have your Thoughts of; and especially with regard to one I asked about some Time ago; namely, Since a skilful Artist does nothing at Random, or without Design, pray what do

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do you take to be the Cause of the great Difference we find in the Revolution of the Planets on their Axis? *Jupiter*, the largest of them, performs more than two Revolutions on his Axis, before *Mars*, or our Earth, though much inferior to him in Bulk, performs one.

P. It is as true on the one Side, *Matbo*, that the great *Architect of Nature* does nothing at Random, or without Design, as it is on the other, that we cannot discover the Reasons in every Particular, why he hath contrived Things so; and this we must readily own, if we consider the infinite Difference between his Knowledge and ours.

M. This is a satisfactory Reason enough why we cannot know every thing; or rather indeed, why we can know but few Things.

P. You see it is not an Excuse contrived for our Ignorance, but a Truth flowing from the Limitation of our Knowledge, when compared with the Divine Intellect: Neither is it a Refuge devised to skreen the Works of the Deity from Enquiry and Examination. The better qualified any Person is to enquire into, and judge of these Works, so much

much the more Art and Skill will he find displayed in them.

M. All this is a plain Consequence of what has been so often said before.

P. To be satisfied therefore that the Divine Art reaches beyond our Faculties, is a negative sort of Knowledge, as necessary to be kept in Mind, as any thing we know most perfectly: And hence, if we would enquire soberly into the Works of Nature, we ought humbly to adore, and reverence a Knowledge superior to our own, even in those things, where we can neither comprehend the *End*, nor the *Means* conducing to it; for this also belongs to sound Philosophy. Otherwise, if once we should imagine we were capable of knowing every thing, we must necessarily fall into the Absurdity of supposing there can be no Reason for ordering things so, because we do not see the Reason.

M. That would indeed be direct Folly and Madness.

P. Much less ought we so rigidly to insist on a Reason for every thing, as to leave nothing to the Determination of the Good-Pleasure and Will of the Deity; in such Cases namely, where the *End* admits of a diversity of *Means* equally conducive to

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it in Nature. For some Philosophers have idly contended, That the Frame of Nature could not subsist, if the diurnal Revolution of the Earth, for Instance, were but a Minute, or half a Minute, longer or shorter than it is. They demand a sufficient Reason for every *Hair's Breadth*; otherwise the Hands of the Creator must be bound up: As if his Good-pleasure were not really the most sufficient Reason in such Cases.

M. This is manifestly absurd, and contrary to common Sense at first Sight. Those affectedly nice Folks, under Pretence of demanding a Reason for Things in themselves indifferent, seem rather determined, I think, to bring the Deity under Restraints at their Pleasure, contrary to Reason. But in the present Question concerning the different Length of the Revolutions of the several Planets on their Axes, that is, concerning the different Length of the Days in each of them, may we not suppose that the Convenience and Pleasure of their several Inhabitants is studied? For in the Planets, which are at the greatest Distance from the Sun, the Comfort of the Inhabitants seems to require that the Darkeness should be shorter, and the Returns of Light more frequent, than

than in those which are nearer the Center of the System. Thus *Mars* and our Earth, whose diurnal Revolutions are nearly equal, seem to have but the same Distance, if compared with *Saturn* or *Jupiter*.

P. We may safely say in general, *Mattho*, that the Convenience and Comfort of the Inhabitants is the End of all those studied Contrivances which are observable throughout the whole System: But it would be rash to be too particular in the Application of this general Conclusion; because we may be too liable to fall into the Mistake of measuring Conveniencies according to our own Constitution on this Globe: Whereas the Nature and Condition of the several Inhabitants, is probably as different as the Globe they reside upon. We have Instances enough of this Diversity of animal Life on our own Planet, to satisfy us that such a Notion is not without Foundation. The *Russian* Bear could as little live on the scorched Plains of *Africa* as the Lion or Tiger among the *Lapland* Snows. Some Creatures we observed sleep for whole Months together: The quick Returns of Light and Darkness do not so much affect those, as the slower Vicissitudes of Summer and Win-

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ter. Some Creatures fly abroad only in the Dark, or charm us with their Musick then, while others are reposed in Silence at the same Season.

M. This indeed I saw before: And among Vegetables likewise, some are fitted to thrive best in a cold Clime, whilst others require a warmer Region; some are of a short Duration, some preserve their Verdure all the Year round; some appear early in the Spring, others later, through all Seasons of the Year. There is, I perceive, an inexpressible Variety of Constitution both in the vegetable and animal Nature; so that I am obliged to you for reminding me of these Particulars on this Occasion. We are apt to require those Circumstances every where, which seem most convenient to our own Condition: Though it must be as absurd to imagine that all Things must be alike in the several Planets, as in all the Climes of the same Planet.

P. Agreeably to this therefore we see, there is a great Diversity in their Revolutions on their Axes: *Mars* and our Earth perform their diurnal Rotation, as you observed, nearly in the same Time; but *Venus* and our Moon take a much longer Space;

Space ; the Day in *Venus* being 23 of our Days, and in the Moon a whole synodical Month ; while *Jupiter*'s Revolution is performed in less than ten Hours, and *Saturn*'s probably is not of much longer Duration. Hence, besides the Convenience you mentioned of the more frequent Returns of Light, another Advantage must accrue to the Inhabitants of those larger Planets, by their swift Rotation on their Axes.

M. What other Advantage ?

CXXXI. P. The Gravity of Bodies on the Surface of *Jupiter* is twice as great nearly as on the Surface of our Earth. Wherefore if we resided on that Planet, we should be a Burthen to ourselves, being pressed down with double the present Weight, and having but once the Strength to support it. But *Jupiter* is more than ten Times larger in Circumference than the Earth : Hence if both Planets revolved on their Axes in the same Time, the centrifugal Force in *Jupiter* would be more than ten Times greater than with us. But the Squares of their periodical Times are nearly as 6 and 1 ; or the Squares of the Number of Revolutions performed in the same

P 3

Time

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Time by the Earth and *Jupiter* are as 1 and 6. Wherefore a Body placed on *Jupiter* will have 60 Times a greater centrifugal Force than with us: Which must be a notable Relief to the Inhabitants of that Planet, although perhaps endued with a greater Degree of Strength than we are.

M. This is an Advantage I did not attend to. And what Part of their whole Weight may it be, of which they are thus eased by the centrifugal Force of their Planet?

P. They are lighter by about a ninth Part of their whole Weight: Or a Body weighing nine Stone at *Jupiter's* Equator, if the Planet stood still, would gravitate with a Force but as eight Stone, upon the Commencement of its diurnal Rotation.

M. That must in Truth be a great Relief. But as *Jupiter* is ten Times larger in Circumference than the Earth, why is not the Attraction, or Weight of Bodies, ten Times greater likewise on his Surface than on our Globe?

P. If the Matter in him were as dense as in our Earth, the Weight of Bodies on their Surfaces would be as their Semi-diameters, or the Distances from their Centers:

ters: But the Matter in *Jupiter* seems to be made less dense with Design. For we can hardly imagine that Men of our Stature, for Instance, could support ten Times the Weight of such Bodies as ours are, with Ease; or have the free Command of Limbs so chained down by their own Gravity. And if we suppose them of a larger Stature, the Inconvenience becomes greater, the least of any Species being always observed to have the greatest Ease and Agility in Motion. And upon the same Account, though *Saturn* be 8 Times larger in Circumference than our Earth, equal Bodies are not 8 Times heavier on his Surface than on the Surface of this Globe; but in the Proportion of 17 to 10; that is, not much above once and a half as heavy.

M. I am almost fully persuaded that this is a wise Contrivance of the Creator, for the Ease of the Inhabitants and Animals residing on those Planets.——But is it certain that Bodies gravitate but twice as much only on the Surface of *Jupiter*, as on our Earth? For this I look upon to be a Point of Importance.

P. It is certain they do not gravitate quite twice as much there as here; but in

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such Cases I choose to give you the nearest whole Number to express the Proportion; because where nothing depends on it, it is needless to trouble you with fractional Expressions, or the decimal Part of an Unit.

M. If it be practicable, pray make me understand this.

P. We are both of us already fatigued.

M. I shall leave you immediately after.

P. The Reason of the Thing is easily shewn: But a Calculation would be tedious.

M. The Reason of the Thing, with an easy Example to illustrate it, is all I desire of you.—

P. First then, Bodies attract at equal Distances according to their Quantities of Matter; a Body having double or triple the Quantity of Matter attracts twice or thrice as strongly at the same Distance, as a Body having but a half or a third Part the Matter.

M. This is plain enough.

P. If therefore two Satellites revolved about *Jupiter* and our Earth, at equal Distances from their Centers; the Forces with which they were attracted would be as the

the Quantities of Matter in *Jupiter* and the Earth respectively.

M. That is but the same Thing in other Words.

P. Their centrifugal Forces likewise (which you know are always equal to the centripetal) should be as the Quantities of Matter in the two central Bodies.

M. That comes still to the same Thing.

P. The Squares of the Number of Revolutions, performed by these Satellites in the same Time, should also be as their centrifugal Forces.

M. This you shewed me to Satisfaction before. And the Squares of the periodical Times are inversely as the Squares of the Number of Revolutions performed in the same Time: For in the Example of our two Moons, the periodical Time of the outer Moon was 8 Times longer than the periodical Time of the *inner*; therefore the Number of the Revolutions of the inner Moon was 8 Times greater, so that 64 was the Square both of the one and the other.

P. From this then it follows, that the Quantity of Matter in *Jupiter* will be to the Quantity of Matter in the Earth, as the Square of the periodical Time of the Earth's

Earth's Moon is to the Square of the periodical Time of *Jupiter's* Moon revolving at the same Distance from him.

M. I perceive all the Steps in this Argument very distinctly ; — but none of *Jupiter's* Moons perhaps revolve at the same Distance from his Center, as our Moon does from the Center of the Earth.

P. Our Moon you know is 60 Semi-diameters of the Earth from its Center : Now you may easily find out in what Time a Satellite would revolve about *Jupiter* at the same Distance from his Center ; since the Cubes of the Distances are as the Squares of the periodical Times.

M. I must suppose then that a Satellite revolves about *Jupiter* at that Distance ; and find the Time of its Revolution by this Proportion ?

P. You must ; and it is easily done : For taking *Jupiter's* innermost Satellite, *v. gr.* whose Distance from his Center is about 55 Semi-diameters of our Earth, and its periodical Time 42 Hours 28 Minutes, or 2548 Minutes ; say, as the Cube of the Distance 55 is to the Cube of the Distance 60, so is the Square of 2548 Minutes to a fourth Number, which will be the Square of

of the periodical Time of a Satellite revolving at 60 Semi-diameters of our Earth from the Center of *Jupiter*. This Number you will find to be about 8428776. The periodical Time of our Moon is 27 Days, 7 Hours, 43 Minutes, or 39343 Minutes, whose Square is 1547871649. Thus the Matter in *Jupiter* will be to the Matter in the Earth as 1547871649 to 8428776; or as 184 to 1.

M. This I shall try as accurately as I am able; — But what is all this to Bodies gravitating only twice as much on the Surface of *Jupiter* as on our Earth?

P. If *Jupiter* were as dense as this Earth, he must have a 1000 Times more Matter than is in the Earth, because Globes equally dense are as the Cubes of their Diameters; 10 and 1, to wit, in this Case. And since the Attraction increases as the Cubes of the Diameters, or Matter; but decreases as the Squares of the Diameters, or Distances; his Attraction on his Surface should be as a 1000 divided by a 100; or as 10 and the Earth's as 1. But his Matter is only 184: Therefore the Attraction on his Surface is only as 184 divided by 100; and the Earth's as 1. That is, the Attraction

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Attraction on his Surface is not twice the
Attraction on our Globe.

M. It could not be twice as great, unless the Matter in him were 200 Times as much as in the Earth; for then 200 divided by the Square of the Diameter [100] would only be 2, while the Earth's was as 1.

P. You are very right.

M. And what is his Density with Respect to the Earth's?

P. Although his Matter were 200 Times as much as that in the Earth, he takes up a 1000 Times the Space, with only 200 Times the Matter. Divide the Matter 200 by the Space a 1000; and you see even then he would be 5 Times rarer than the Earth; or have but a fifth Part of its Density.

M. Well, I am extremely pleased with all this; and am now fully persuaded that this Rareness of Contexture in those larger Planets was wisely designed for the Sake of Inhabitants residing upon them, who otherwise must have been oppressed by their own Weight. — In what Time would this other Satellite revolve about *Jupiter*,

at

at the Distance of 60 Semi-diameters of the Earth from his Center?

P. The Matter in *Jupiter* is the Square of the Number of Revolutions it would perform, while our Moon revolves once about the Earth: And the Square Root of 184 is 13, 5. It must therefore revolve 13 Times and a half about *Jupiter* in the Time of our periodical Month. Or the Square Root of the other Number 8428776, viz. 2903, 2 is the periodical Time of this Satellite in Minutes; which comes to 48 Hours 23 Minutes.

M. I think I now understand enough to initiate me into these Calculations: Wherefore I shall not give you any farther Trouble at present.

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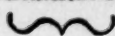
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As the Weight of Bodies on the lesser Planets is but small, their Rotation on their Axes is slow, and their centrifugal Force but weak. Heat and Light are dispensed rather according to the Surface, than the Quantity of Matter in the luminous Body; hence the Sun is but of a moderate Density. That the uttermost and innermost of the Planets are not uninhabitable by Reason of the Extremities of Heat or Cold. Heat is not always in Proportion to our Vicinity to the Sun: Cold requires a positive Cause, or something more than the mere Absence of Heat. The Extremities of both may be qualified by the Constitution of an Atmosphere. That all the Planets are surrounded with Atmospheres. The physical Explication how Bodies may describe elliptical Orbits about an attracting Body, placed either in the Center of the Ellipsis,

Ellipsis, or in one of its Foci; according as the Law of Attraction is supposed different. These two Cases compared between themselves, and the Transitions from the one to the other shewn natural and easy. The Proportion between the Squares of the periodical Times and Cubes of the middle Distances, still observed when Bodies revolve in Ellipses. The Comets revolve by the same Laws, and observe the same Proportions as the Planets. — Of the Immortality of the Soul. That the Soul is not assisted to think and perceive by Organs of a dead Substance; but is by these confined and limited to a particular Manner of Action and Perception. Whether the Deity could cut off rational Beings, for whose sake the material World was created; the Frame itself still remaining. The Desire of Existence the Foundation of all our other Desires, and the Source of all great and virtuous Actions. A happy Existence the only Object of Desire in the Nature of Things. Utter Extinction no Object of Desire. The Disingenuity of the Atheist. The Mistake of those who separate Virtue from a Love to ourselves. Atheists could not live together in Society

on their own Principles. The false reasoning in Mr. Bayle's Apology for the Atheists. The Atheists Account of the Rise of Religion. The Wonders in the material Creation designed to instruct Beings appointed for Immortality. The material Creation the inferior, and least wonderful Part of the Works of God.

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CXXXII. M. **Y**OU see me here once more, *Philon*; and to begin where we left off —

P. You begin abruptly enough, I think, *Matho*.

M. There is no need of resuming what was said last. I understand it tolerably well; nor would I deceive my self in a thing of this Nature. — I am much in Love with what you told me concerning the Quantity of Matter, and Density of the Planets, as also concerning their centrifugal Force, while they turn round on their Axes. But what is the Reason that we cannot find out the Quantity of Matter in *Mars* or *Venus*, as we do in *Saturn* or *Jupiter*? This, I remember, you said was not known.

P. The Reason is, because they have no Satellite (none conspicuous to us I mean) revolving

revolving about them. Had they Satellites revolving about them, whose Distances and periodical Times were known, we could discover in what Time a Satellite should revolve about either of them, at any assigned Distance; and thereby compare their Quantities of Matter, and Densities with those of any other Body in the System.

M. Of any other primary Planet, you mean, which hath a Satellite revolving about it?

P. That I ought to have said.

M. Then we cannot know the Weight of Bodies on their Surfaces; nor compare that with their centrifugal Forces?

P. We cannot; though the centrifugal Force on *Mars* must be considerably less than on our Earth, both because his Rotation on his Axis is somewhat slower, and his Diameter is much shorter; and on *Venus* the centrifugal Force is quite inconsiderable: But then, as these are only small Planets, the Weight of Bodies upon them cannot be very great. In *Venus* it may be nearly the same as on this Globe; and were we on *Mars*, we could not feel much above half our present Weight.

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M. It was reasonable that the centrifugal Force should be small, where the Weight was otherwise tolerable: For I now see that, the more swiftly any Planet revolves on its Axis, the more the Weight of Bodies upon it must be diminished.

P. Undoubtedly: For these two Forces act contrary to each other in this Case, as much as in the Revolution of Planets round the Sun; since the centrifugal Force of Bodies proceeds from the Inertia of Matter, by which they always tend to move on in the same Direction.

M. But in the Revolution of Planets round the Sun these two Forces were in Equilibrio.

P. The Reason of that, you remember, is, lest the Planets should be drawn down to the Sun, or run out to a greater Distance from him; as the one or the other of these Forces prevailed: Whereas, had they been in Equilibrio here, Bodies would not at all have gravitated to their proper Center. Not only our Bodies would not firmly have participated of the Earth's diurnal Rotation, but our Houses must have been loose and tottering, or in constant Suspense betwixt standing and falling (for it is not easy to imagine

imagine the Case exactly); nor could the Ground itself have been a firm Support and Foundation for any thing.

M. I perceive something here which I cannot well express.

P. Nor can I understand it, unless you express it in some Way or other.

M. It was as necessary that the centripetal Force should prevail over the centrifugal, with respect to the diurnal Rotation; and that in a different Degree, according to the different Weight of Bodies on the larger and lesser Planets; as that *these Forces* should balance each other with respect to the annual Revolution: And in both Cases we see them wisely adjusted in great Variety of Circumstances. In short, it is new Matter of Admiration, to see the centrifugal Force weak where the Gravitation is small, and strong, where the Weight of Bodies becomes greater.

P. The Observation is just; and the Expression at least intelligible. —

M. But in what Time must our Earth have turned round on its Axis, so as to have made these two Forces equal?

P. The centrifugal Force at the Equator (where it is greatest) is to the centripetal

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Number 289 is 17.

M. Pray let me go on with the rest of the Argument by myself. — Since the centrifugal Force is increased with the Square of the Number of Revolutions performed in the same Time; if the Earth performed 17 Revolutions in the Time it performs one, the centrifugal Force at the Equator would have been 289 times greater than it is at present, and therefore equal to the Weight of Bodies there; which consequently must have been in constant Suspense between flying off from the Earth, and remaining on its Surface: So that a small Force must have given them a Motion to any Side, just as if they had been quite without Gravity.

P. You deduce the Argument very accurately.

M. But pray what would be the Consequence, if the Earth rolled round a little more swiftly than at the rate of 17 Revolutions in 24 Hours?

P. From what you have said just now it follows, that all Bodies at the Equator would then be thrown off from the Surface Eastward: But by the Action of Gravity retracting them, they would fall back again.

to

to the Earth. And thus they would constantly be cast off and fall back without ceasing; nor could any thing be firmly settled in one Place, but as it lay nearer the Poles, where the Rotation was less violent.

M. This would be a wild Confusion for a habitable Globe! — But let me recollect a little. —

CXXXIII. Seventeen Revolutions in twenty-four Hours is, I think, one Revolution in less than an Hour and a half.

P. It is one Revolution in an Hour and about 25 Minutes.

M. Then, as it appears to me, you argued inconsistently before, when we were speaking of the diurnal Rotation of the Earth, where you supposed that it might turn round on its Axis every quarter of an Hour; since in that Case every thing must be thrown off from its Surface with inconceivable Rapidity: Or rather the whole Mass would be shaken quite asunder, except perhaps a small Quantity about the Axis of its Motion.

P. You urge the Consequence very well; the whole Mass would then be shaken quite loose: Notwithstanding I have a right to make



make that Supposition, because you know it is equally possible, that the Gravity of Bodies should be augmented, as that the diurnal Rotation of the Earth might be accelerated, and that to any Degree; for it belongs equally to the same Power to effect a Change in either. The Supposition was therefore consistent enough, and proper to the Subject we were then discoursing upon. For in that Case you could less have perceived the Motion of the Earth by the Help of your Senses, than at present; since the Heavens and heavenly Bodies must have appeared to roll over our Heads west-ward, with greater Velocity than a Bird flies.

M. I understand; *That Supposition is consistent, which does not imply a natural Impossibility.* And your Argument was as if you had said, "Had it pleased the Almighty Creator, so to increase the Gravity of Bodies, and accelerate the Earth's diurnal Rotation, that it should have rolled round on its Axis in such a Time." — After this please to shew me in what Time Jupiter must have rolled round on his Axis, so that the centrifugal Force of Bodies on his Surface might have been equal to their Weight or Gravity?

P. This

P. This you ought now to find out for yourself, since you have the Distance and periodical Time of his innermost Satellite.

M. It is true; for I have already half of my Work done in the last Example. Then, since Bodies on *Jupiter's* Surface are 10 Semi-Diameters of our Earth distant from his Center; it will be, as the Cube of 55 to the Cube of 10; so the Square of 42 Hours 28 Minutes, or of 2548 Minutes, to a fourth Number, which must be the Square of *Jupiter's* periodical Time on his Axis, that Bodies on his Surface might have their Gravity and centrifugal Force equal. Or it will be as 166375 to 1000, so 6492304 to a fourth Number.

P. Which fourth Number you will find to be 39022; and the Square-Root of 39022 is 197, 5 Minutes; or 3 Hours 17 Minutes.

M. What is the exact Time of *Jupiter's* Revolution on his Axis at present?

P. Nine Hours 56 Minutes.

M. *Jupiter* then performs but three Revolutions for one, that Bodies on his Surface may have their centrifugal and centripetal Forces equal; whereas our Earth should perform 17 Revolutions for one.

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P. The Reason of which is, because a great Part of the Gravity of Bodies on the Surface of *Jupiter* is taken off, by his swift Rotation at present.

M. Right. I see now that a ninth Part of their whole Gravity is taken off by their present centrifugal Force, as you told me before; or the centrifugal Force is but 9 times greater, when the whole Gravity is taken off; since it is as the Squares of the Number of Revolutions performed in the same Time, 3 and 1.

P. You have it exactly.

M. From this then I now also understand more clearly, what we have once or twice touched upon before; namely, why the Earth is higher about the Equator, and more flat and sunk about the polar Regions; which Inequality ought, I think, to be more remarkable in *Jupiter*.

P. What are your Thoughts of that Particular now?

M. From the greater centrifugal Force about the equatorial Parts, the Matter there is relatively lighter; and is therefore more raised to make an Equilibrium.

P. The Inference is just; and on our Earth the Matter of Fact is confirmed both

by

by Measuring and other Experiments: But on *Jupiter*, whose diurnal Rotation is swifter, and the centrifugal Force therefore greater, the Inequality, as you observe, is still more plain. For whereas in the Earth the equatorial Diameter exceeds the polar, but by one 230th Part of itself, or they are as 230 to 229; in *Jupiter* they are to each other as 11 to 10 nearly.

M. That is a notable Difference, and agrees well to his centrifugal Force.

P. The Difference is almost as great as the whole Diameter of the Earth, which is but about a 10th Part of *Jupiter's*.

M. Here again, I think, something is naturally suggested to us.

P. What?

M. That the Planets were first formed, and made spherical by the mutual Attraction of their Parts, before they received their diurnal Rotation: For this Rising, or Swelling, about the Equator seems naturally to have been induced on a former spherical Figure.

P. It must indeed appear so to us in the Order of Nature.

M. Since then we must conceive the Planets as first without their diurnal Motion,

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tion, we may with Pleasure see, as it were, this Rotation impressed on those prodigious Globes, by the Almighty Hand of the Creator.

P. I agree with you. One, who considers Things in this philosophical View, will feel all the Pleasure you mention, in thus tracing the Original of the diurnal Rotation. And it appears somewhat inartificial first to suppose that the Deity moulded the Planets into this oblate spheroidical Figure (as it is called); and that then he impressed a Motion upon them which must of itself naturally have produced that Figure. For, as you well observed in our fourth Conference, the Attraction of Gravitation leaves Matter still in the most fluid Form possible: So that a Body once brought into a spherical Figure, by this Affection between all its Particles, must necessarily, by a Rotation on an Axis, be elevated about the Equator of its Motion, and thereby become an oblate Spheroid.

CXXXIV. M. Pray what may the Weight of Bodies be on the Surface of our Moon?

P. If

P. If the Earth and Moon were of the same Density, Bodies there could have little more than a fourth Part the Weight they have here, according to the Diameters of the two Planets. But because of the greater Density of the Moon, the Gravity of Bodies on the Earth is to the Gravity on her Surface as 293 to 100: That is, were we there we could not feel much above the third Part of our present Weight.

M. Much centrifugal Force on that Planet then must have been, I think, inconvenient, as rendering Bodies too light. — After this it would be needless to ask what the Weight of Bodies might be on the Surface of the Sun, since he cannot be supposed habitable; and the Gravitation of Bodies must be excessively great, so near the Center of Attraction of the whole System.

P. It is not so great as you may imagine, *Matho*: Heat and Light are dispensed rather according to the Surface than the Density of the Body, or the Quantity of Matter in it. Hence the Sun is not one of the densest Bodies of the System. And the Gravity on his Surface is reckoned but about

about 24 Times more than that on the Surface of the Earth.

M. I see it is reasonable that the Light shined round, and perhaps the Heat too, should rather be as the Surface of the luminous Body, than as its Density; but I had quite other Notions of the Attraction or Gravity so near the central Body: Make me understand therefore, if you please, how this should be?

P. The Quantity of Matter and Density in the Sun is discovered the same Way as the Quantity of Matter and Density in *Jupiter*; namely, by computing in what Time our Moon would revolve about the Earth, at the same Distance from it as *Venus* is from the Sun. — As to the Density of Bodies, and Gravity on their Surfaces, you may perhaps get an easy general Notion of these, by considering the two following Cases as *Extremes*. If the Matter in the Sun and Planets were as the Cubes of their Diameters, they must all have the same Density, and the Weight of Bodies on their Surfaces must be directly as their Diameters: For the Attraction increasing as the Matter or Cubes of the Diameters, and decreasing as the Squares of their Diameters,

meters, the Cube divided by the Square would always give the Diameter to represent the Attraction of the Surface.

M. This was observed before.

P. But if the Matter were only as the Squares of the Diameters, the Density would be inversely as the Diameters; and the Weight of Bodies would be the same on the Surface of all Planets, let their Quantities of Matter be ever so unequal.

M. I understand nothing at all of this.

P. Suppose there are two Planets whose Diameters are 1 and 10; and if, in Order to find out their Densities, you divide the Matter (which is as the Square of the Diameter) by the Space it takes up (which is as the Cube of the Diameter), it will be 1 divided by 1, for the first Planet; and a 100 divided by a 1000, for the second: Or their Densities will be 1, and one tenth.

M. Thus far I see: The second will have but one tenth the Density of the first, as its Diameter is ten Times larger. Thus if the Matter in *Jupiter* were but a 100 Times the Matter in the Earth, he should have but a 10th Part of its Density, or be 10 Times more rare.

P. And

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P. And the Weight of Bodies on the Surfaces of all the Planets would then still be the same: For the Attraction increasing as the Matter, or Square of the Diameter, and decreasing also as the Square of the Diameter, the Square of the Diameter divided by the Square of the Diameter will always be equal to Unity, how different soever the Diameters may be among themselves.

M. Now you have given me Satisfaction; for I understand the Consequence of both Suppositions, either when the Matter is as the Cubes, or as the Squares of the Diameters. And as any particular Instance draws near to the one or the other of these Cases (which you call *Extremes*) the Gravity on the Surface of that Planet will be more or less accordingly.

P. Both Cases may be exemplified in one and the same Body, the Quantity of Matter in it remaining also the same; only by supposing its Diameter different.

M. Pray shew me how?

P. If the Diameter of the Sun be supposed a 100 Times the Diameter of the Earth, and the Quantity of Matter as the Cubes of their Diameters, their Densities will

will be equal, and the Weight of Bodies on their Surfaces directly as their Diameters: But if the Diameter of the Sun be supposed a 1000 Times the Diameter of the Earth, the same Quantity of Matter remaining, their Densities will be inversely as their Diameters, and the Weight of Bodies the same on both their Surfaces.

M. I conceive it: Though the Matter in the Sun be still a million of Times more than the Matter in the Earth; in the first Supposition it is as the Cube of the Diameter a 100, and in the second as the Square of the Diameter 1000: And the Surface of the Sun in the last Case being 10 Times farther from the Center, than in the first, the Attraction there will be a 100 Times less, or equal to the Attraction on the Surface of the Earth. This is agreeable enough, and gives me a more familiar Notion of these Things.

CXXXV. *P.* You see then by what artful Methods, of more or less Density, and more or less centrifugal Force, it comes to pass, that the Weight of Bodies on the larger and lesser Planets, is not near so different as the different Quantities of Matter

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Matter in the Planets would seem to im-
port?

M. I see every Thing in the System con-
sistent, if the Planets are considered with
a View to *Habitation*; whereas without
that, the Design seems broken and incohe-
rent.

P. Especially if we suppose the Earth
alone designed to be habitable; while the
Rest are left solitary and unfrequented.—

M. Notwithstanding there seems to re-
main still one Inconvenience.

P. What is it?

M. That the Heat of the Sun cannot
be multiplied at the Extremities of the Sys-
tem, by Reflection, as his Light is. The
hundredth Part of our Heat must make
Saturn but a comfortless Place.

P. As we saw before, *Matho*, that the
animal Constitution, with Respect to Heat
and Cold, may be widely different on the
same Planet; so there may not be such a
Difference of the Degrees of Heat and
Cold, on the Planets nearer to and more
remote from the Sun, as we imagine. The
Causes of Heat are more than one, as we
may observe by what happens in the Bow-
els of the Earth, in *Fermentations*, in E-
bullitions,

bullitions, even in our own Bodies ; and especially by common Fire. *Cold* likewise seems to imply something more than a mere Privation of Heat, and to depend on some very active Principle. This will appear more probable, if we consider the violent and sudden Effects of Cold, in some common Experiments of artificial freezing ; and when the Barrel of a Gun, or the Shell of a Bomb, though of considerable Thickness, is violently burst by the freezing of the Water contained in it ; that shews quite another Sort of Principle, than the mere *Inertia*, or Sluggishness of the Particles of Matter. The Rays of the Sun are certainly productive of Heat ; but (by the Accession, or Co-operation of some other Cause) not always in Proportion to their Density, or the Vicinity of the Body to the Sun : Otherwise we should always have the same Degree of Heat or Cold, at the same Time of the Year, regularly in a Circle ; which nevertheless you see we have not.

M. This is indeed common Experience, and seems to prove easily what you say. I have often observed very soft Weather, and mild Nights in the Depth of Winter, when a long Frost has been succeeded by a quick

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Thaw ; and contrarily, bitter Winds and a frosty Air, when the Sun has been near the Summer Solstice.

P. This seems to proceed from the Constitution of our Atmosphere, and the Alterations happening in it ; which produce sometimes sultry Heat, and sometimes piercing Cold, directly contrary to what should be the Effect of the Sun's Rays separately considered : So that *Heat* and *Cold* do not absolutely depend on a Planet's Nearness to, or Distance from the Sun, but together with these, on some other Causes. We are considerably farther from the Sun in the Summer Months, than in the Winter, and for all that our Weather then is generally much warmer. — Now, though *Saturn* has but about the hundredth Part of the Sun's Heat which we feel, I am not sure if the hundredth Part of our Heat will amount to any Degree of positive and real Cold, without the Co-efficiency of some other positive and real Cause. And it is not difficult, I think, to conceive, that the Constitution of his Atmosphere may be such, as to make that Planet a mild and temperate Clime. And if there be any Weight in this reasoning, it will not be hard

hard to apply it to the inferior Planets, *Mercury* and *Venus*; for we sometimes feel the Heat of our Summer as much qualified by some different Cause, as the Rigour of our Winter.

M. There is indeed so much Reason in all this, that at least I shall not be so rash in drawing Inferences from narrow Principles in this Affair, as otherwise I should have been. One Thing notwithstanding surprizes me; *viz.* why the Earth should be farther from the Sun at one Time than another: But before I ask you concerning this Particular, I beg you would tell me, why you suppose there is such an Atmosphere about each of the Planets, as about our Earth?

P. I must suppose there is an Atmosphere about every one of the Planets, unless I would imagine them to be Globes of Adamant, or something still more hard. Every Thing about our Earth is in constant Change: I am not certain if we can except any Species of Bodies that can be named. Metals themselves seem gradually to decay, as well as come to a State of Maturity. Every Thing therefore contributes its Share to the Atmosphere, which is an

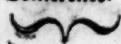
heterogeneous Mixture of all Sorts of Particles. Thus, unless we would suppose that the Matter in the Planets is not acted upon in the same Manner as the Matter in our Earth; which would be a Supposition without Foundation, and contrary to Reason; we must conceive that they have Atmospheres about them, like to that which is about the Earth. A Degree of Repulse (less or more) is the Principle of Dissolution of all natural Bodies, if we may speak mechanically on this Head, and without considering the immaterial Cause of this Repulse: And repellent Particles are most fit to join themselves with the Atmosphere, and to become a Part of it. It is this Principle which occasions what is called *Effluvia* from particular Bodies: And the Effluvia of the Planets (if I might be allowed so to speak) constitute their Atmosphere.

M. I am afraid you are going too deep with me, though hitherto, I think, I understand what you say with Pleasure: But what I meant by my Question was, Whether the Atmospheres of the Planets can be discerned by Observation?

P. It is not necessary to the Constitution of an Atmosphere that it should have visible

ble Clouds, and thick palpable Fogs: Our Atmosphere exists no less when the Air is serene and clear, than when it is heavy and clouded. It is observed that the highest of the Clouds, when their Height is measured, are not found to reach above a Mile from the Surface of the Earth: But allowing them to be two or three Miles high; what is that to the Distance of the Planets? To suppose that Observation might determine here, is to suppose the Object within the due Distance; which is the Mistake in several other Cases. Our Atmosphere, how high soever, transmits the Light of the fixed Stars to us, as you observed before: And if we may reason from Analogy, the Atmosphere of other Planets should do the same. Besides, as far as Observation can reach, both our Moon and *Mars* are discovered to have Atmospheres: In the Ap-pulses of *Mars* to the fixed Stars, they are observed to become obscure and dim; and in total Eclipses of the Sun, the Moon's Atmosphere becomes perceptible.

M. It seems indeed, wherever there is Heat and Moisture there must be Vapours; and consequently an Atmosphere.



P. Nay, wherever there is Cold there must be an Atmosphere; for Vapours are observed to rise plentifully in the hardest Frost,

CXXXVI. *M.* Pray tell me now, if it be true that we are nearer the Sun in the Winter than in the Summer; how comes it to pass that we feel so much more Cold when nearer him, than when farther distant from him?

P. You should have proposed this Difficulty, *Matbo*, long ago; for when you supposed that our Distance from the Sun was always the same, you should either have asked this Question then, or inferred, because we were equally near the Sun, Summer and Winter, that we must have had the same Degree of Cold all the Year round.

M. I'm afraid my Question is not so much to the Purpose as I imagined.

P. It is obvious that the Rays falling more or less obliquely on the Surface of the Earth must occasion a great Difference in the Degrees of Heat. Hence it must be less when the Sun arises but a little above our Horizon in the Winter, than when he mounts higher, and darts his Rays more
perpen-

perpendicularly upon us. You find when you hold any Thing directly opposite to the Fire, it is more strongly heated, than when you turn it side-wise at the same Distance.

M. I perceive it must be so: But in what Proportion will this oblique Incidence of the Sun's Rays increase or diminish the Heat, the Distance being the same?

P. I am not sure if the Proportion which seems just to me will appear so to another.

M. Tell it me however: A Guess sometimes helps us to come nearer the Truth afterwards.

P. 'Till you can come at something more authentick then, you may suppose that the Density of the Rays, and therefore the Degree of Heat, will be as that Line which is called the *versed Sine* of their Inclination, or Angle of Incidence.

M. Shew me this by a Figure?

P. You may see it from any Circle. In this Figure, if the Sun be perpendicular over the Plane, the Rays will be the densest possible at that Distance; and their Density may be expressed by the Radius. But if the Sun be in this Position (suppose 32 Degrees from the Vertex) drawing a Line

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from him to the Center, none of the Rays on the upper Side of the Line, you see, will fall upon the Radius, and those only on the under Side are now spread over it all. But these are only the Rays which fell upon *this Part* of it, when the Sun was vertical; which Part is the versed Sine of the Angle of Incidence of the Rays.

M. So it appears indeed from the Inspection of this Figure: And at this Rate what may be the Proportion of our Heat in Winter to that in Summer?

P. If this Proportion be just, abstracting from the Difference of Distance, and all other Causes of Heat, except the Density of the Rays, our Heat in Winter will be about the six and twentieth Part of what it is in Summer. For supposing our Latitude 55 Degrees and a half, the Sun's greatest Altitude in Summer will be 58 Degrees, and in Winter only 11; the versed Sines of these are 4849619 and 183728, which are nearly as 26 and 1.

M. All this I understand, and am satisfied that the six and twentieth Part of our Summer's Heat is no Degree of Cold: For it is still Heat perceptible to Sense. And how great may our Heat in Summer be, with

with Respect to the Heat at the Equator, when the Sun is vertical to them?

P. Our Heat must be about half of theirs; for the versed Sine of 58 Degrees is somewhat less than half the Radius.

M. This Proportion will farther shew us the Density of the Sun's Rays at any Time of the Day, as well as any Time of the Year, according to his Altitude?

P. If it be just in the one Case it must be so in the other.

M. I see no Objection against the Justness of it, at present; and even though it should not be precisely just, thus much seems certain, that another Cause mixes itself with the Effects of *Heat* and *Cold*, besides the greater or less Density of the Sun's Rays, or even his total Absence. — Now, as to the Earth's being at a greater Distance from the Sun, in Summer than in Winter; if this be so, I know not what to say. I thought a Body could not have revolved about the Sun in any other than a circular Orbit, without being drawn down to him, or running out through the celestial Spaces; and this Notion you seemed to approve of: This stumbles me exceedingly.

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P. In all such Subjects, *Mathe*, People generally begin, you know, with the easiest Cases: To tell them of more intricate and difficult Things at first would only tend to discourage them. And that is the simplest Case of one Body's revolving about another, by the Composition of an attractive and projectile Force, when it moves in a circular Orbit. As this Case is plain, you easily conceived it: Yet it is no less true that a Body may describe about another an *oblong* or *elliptical Orbit*. This is more difficult to be conceived, but it no Way invalidates the Truth of what you already know. The Orbits of the Planets are not exactly circular, yet they differ not much from real Circles, having but a small Degree of Excentricity. This Method was intended, not to stumble you, but for your more easy Conception.

M. You satisfy me as to the Reasonableness of the Method, which I ought to leave entirely to you; if it were possible to observe a Method in such a loose Discourse, where so many Things offer accidentally. But can I be made to understand how a Body may describe an *oblong* or *elliptical Orbit* about another, without falling quite
down

down to it, or running out through the ambient Space?

P. Not perfectly, I am afraid. It will require too many Words, and many childish Suppositions. Great Men understand this in their own superior Way, without accommodating themselves to our Conceptions.

M. An imperfect Notion is better than none at all. The more childish your Suppositions are, the more they will suit my Capacity; And as for Words, I told you, I often discourse for whole Hours together, without any other Advantage than having got rid of so much Time. And at worst, as we are by ourselves, there can be no Harm in making a Trial, though it should prove unsuccessful.

P. Well, on these Terms we may make a Trial: It will be but a little Labour lost. —

CXXXVII. But before we begin, it will be necessary to acquaint you with some general Things concerning the *Ellipsis*. Here is the Figure itself. It is described about two Points, as the Circle is about one. These Points (marked with the Letters

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ters F and f) are called its *Foci*. As these Points may still recede farther from, or draw nearer to the middle Point, or Center C, the Ellipsis may be more or less oblong, that is, more or less eccentric, 'till it becomes a *straight Line* on the one Extreme, or coincides with a Circle on the other.

M. This is plain enough; for I have seen Carpenters draw such Figures on the Floor, about two Pins, with a double Cord and a Piece of Chalk, when they were going to make an *oval Table*: And we have sometimes diverted ourselves in drawing the like Figures, when the Workmen were gone.

P. Then your Diverſion will prove a Means to facilitate the Matter to you now. Theſe two Lines, which croſs each other in the Center at right Angles, are the *greater* and *leſſer* Axis. If the Attraction be to the middle Point, or Center, when the Body, moving in the Perimeter of the Ellipsis, comes to the Extremity of the leſſer Axis here, it will be at the neareſt Diſtance to the central Body; and at either Extreme of the greater Axis, the fartheſt from it. But if the Attraction be to this *under Focus F*, when the revolving Body comes

comes to the Extremity of the lesser Axis, it is said to be at the middle Distance from the attracting Body: For from the Focus to the Extremity of the lesser Axis, is a *Mean* between the greatest Distance, when the revolving Body is in the *upper Vertex* (or farthest Extremity of the greater Axis) and the least Distance, when it is in this *nearer Vertex*.

M. Let me consider a little this last Particular. — The middle Distance then must be equal to half the greater Axis: For if I add the Eccentricity to half the greater Axis, that makes the greatest Distance from this *lower Focus*; and if I take away the same Eccentricity from half this Axis, that makes the least Distance.

P. You are perfectly right. And this is all that is necessary to trouble you with at present.

M. These Particulars I can easily remember. But something you insinuated in your Description of the Ellipsis appears quite strange, and is more than I expected.

P. What was it?

M. That a Body may move in the Perimeter of an Ellipsis, by the Composition of an attractive and projectile Force, either
when

MATHO: or, The

when the attracting Body is in the Center of the Ellipsis, or in one of its Foci.

P. The revolving Body must describe an elliptical Orbit, as well in the one Case as in the other, according as the Law of Attraction is supposed different; which perhaps you may understand hereafter, if I can hit upon an easy Way of communicating these Things to you.

M. I am to the last Degree impatient to hear this: For, if I might speak my present Sentiments, the Thing seems to me utterly impossible.

P. In the mean Time it would not be amiss to acquaint you with another Particular, though it be not absolutely necessary; and I am afraid it may be difficult too.

M. Pray tell it me at a Venture: The more preparatory Things I have, the more easily I shall understand what follows.

P. If a Body revolve about a Center, by the Composition of an attractive and projectile Force, and if a Line from the Center to the Body be supposed to move along with the Body, that Line will sweep, or run over, equal Spaces in equal Times.

M. You

M. You mean, if we suppose the Time divided into Minutes, or small Portions, the Line in any Minute will sweep over a triangular Space, which will be equal to the triangular Space it runs over in any other Minute?

P. That is the Thing.

M. So far then I think I understand, that if a Body be supposed to move along a right Line with an equable Celerity, if we take any Point without that Line, and imagine Lines drawn from that Point to the Body, at the end of equal Times, the Triangles must all be equal, as having equal Bases and the same Height.

P. Then you have got over the Difficulty of this noble Theorem; for it is founded upon what you have said.

M. Could you shew me a Figure to help me a little?

P. Here is a large, intelligible Figure; and the Thing explained in Words.

M. Let me read and consider this.

P. Don't be in a Hurry; but go through the Argument at Leisure: You are under no Obligation to understand these Matters at first Glance. —

M. What

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M. What I have hitherto seen is not difficult. — I think I conceive the whole. It depends on two easy Propositions in *Euclid*: And as to the Body's moving in the Diagonal of a Parallelogram, when urged by two different Forces, I make a shift to understand that from what you shewed me concerning the Frog carried along the Diagonal of a Square, by the Composition of its own Motion with the Motion of the Plane. On the same Account it must have been carried along the Diagonal of a Parallelogram by a little Change of the Direction and Velocity of the two compounding Motions.

P. I find you really understand it; however consider it over again: We get larger and firmer Notions of any thing by a second Examination of Particulars. —

M. I fancy I understand it tolerably well, and am glad I bestowed the little Pains on *Euclid* which I did, when I find the easiest Things in that Book assist me to make out these Matters: This encourages me to be more diligent. — I see there is no begging of any thing here; one is forced to own that the revolving Body must necessarily describe equal Areas in equal Times, by Rays drawn from

from the Center to it; and that it must move in a Curve, if we divide the Time in very small Parts, and make the Triangles very narrow; since the attractive Force acts incessantly. — This is delightful! I see, if the revolving Body should be brought nearer the Center, it must necessarily be carried about with more Celerity, that the Swiftness of the Motion may compensate the Smalness of the Distance, in order to describe as large an Area in an equal Time, as when it is farther off. And on the same Account, it must be carried more slowly when more remote; still to preserve the equable Description of Areas.

P. Your Observations are very just, and natural: We need say no more on this Head.

M. Let me look at the Book a little, before I return it. — This is Sir *Isaac Newton's* own Book! Then I am not a little pleased with myself, that I have made out a Proposition of this Great Man's, from his own Words. Here is his Picture: What a thoughtful Face is this! and how mild and sweet too!

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CXXXVIII. *P.* These Things premised, you must in the next Place observe that a Body thrown up perpendicularly to any Height, acquires the same Force and Velocity in falling back again, with which it was projected.

M. This must be the Case, I suppose, when I throw a Stone perpendicularly upward; it falls back in the same Track, and with the same Velocity.

P. The Resistance of the Air may perhaps occasion a small Variation; otherwise the Maxim is in itself plain. For the Body receiving an equal Number of Impulses from its Gravity in ascending or descending, and those equally strong in equal Distances from the Center, whether it ascends or descends; the last will restore to it all the Force and Velocity, which the first took from it.

M. This is not difficult to be conceived; for since *falling* (or moving to any Point) is not the Action of Body, more than *rising* (or moving from that Point;) it must require an equal Force impressed, to make the same Quantity of inert Matter move through the same Space, whether toward, or from the Center.

P. And

P. And since the Space is the same, and the Efficacy of the Cause the same in the same Distances, the Time must be the same also.

M. So I understood it. Therefore if a Stone were dropt from a Height, and thrown up again with the same Force it had acquired from the Impulses of Gravity in falling, it would mount to the same Altitude from which it had first begun to descend: The Force it had acquired in falling would be spent in rising, by the contrary Impulses of Gravity, in the same Space and Time.

P. You are right: This is the same Case considered in a contrary View, or taken backward. And it will be equally true, whether we suppose the Body thrown up from the very Center of Attraction, and falling back to it, or from some Height above the Center, and falling back to that Height only.

M. The Reasons already mentioned must be equally applicable to either of these Suppositions.

P. It must also be equally true, tho' the Body should not be thrown perpendicularly upward, but with an Inclination to one Side; for if it rise and fall through equal Spaces,

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it must lose and acquire equal Forces, by the contrary and conspiring Impulses of Gravity in equal Times.

M. This is still equally reasonable. If I throw a Stone on plain Ground, so that it descend as far as it ascended, it must have the same Force when it falls, as when it rose. And if it were struck back with the same Force it had in falling, it would, I conceive, return to me in the same Path.

P. Without doubt; for if you had thrown the Stone from that Part at first, with the same Force, and the same Degree of Elevation, it must have moved in the same Path, from the one Side, as well as from the other.

M. I have often observed in playing at *Shittle-Cock*, that it was because we struck it always with equal Force, and in the contrary Direction, that it described still the same *Curve*, or *Arch* as it were, backward and forward, between each other's *Battledoor*.

P. The Example you bring is proper enough to assist the Imagination: And if a Stone, or any *Projectile* whatever, were still thrown back with the same Velocity, and in the same Elevation, it would describe the same Path exactly, forward and backward for ever.

M. This

M. This Case where the Body is projected with a Degree of Elevation, may be brought, I think, to coincide with the former, where it is thrown directly upward. For if we suppose a plane to move equably along with an horizontal Motion, and a Body to be projected directly up from it; this Body to one not carried along with the moving Plane, will appear to be projected with a Degree of Elevation. Now if it be true with respect to the moving Plane, to which the Projection is perpendicular, that the Body hath an equal Force and Velocity at equal Heights, both in its rising and falling; this will be equally true with respect to a Spectator off at a Side, who sees the Body really describe a Curve, or Arch. Here the Body is impelled by two Forces; one communicated to it by the Plane, with which it is equably carried along, and another by the Cause which gives it the perpendicular Projection upon that Plane. These two Forces do not disturb or confound each other; because a Spectator carried along, sees the undisturbed Effect of the perpendicular Force; and an immoveable Spectator at a vast Distance above, would perceive the undisturbed Effect of the horizontal Force. So when we throw a Body

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with a Degree of Elevation, the Force impressed upon it is equal to the Composition of two Forces, the one impelling it perpendicularly upward, and the other horizontally forward: And these two Forces no more disturb each other's Effects, than if the Body had a plane moving equally along under it.

P. You assist yourself extremely well, *Matho*, in conceiving the separate Effects of Forces thus compounded, which are wont to perplex us in the Beginning.

M. I thought your Supposition of *the moving Plane and the Frog* somewhat ludicrous at first; but I have found it very useful since.

P. But tell me, when you throw a Stone with a small Degree of Inclination to one Side, what is the Reason that it does not go on in one uniform Direction, as when you throw it perpendicularly upward?

M. When I throw it perpendicularly upward, the projectile and attractive Forces act in the same straight Line; so that there is no Force acting on any Side, to draw it out of this uniform straight Direction: But when I give it the least Degree of Inclination to one Side, these two Forces constantly act in
different

different Directions, and the Body must constantly change the Direction of its Motion, or move in a Curve.

P. You will not retract this Concession afterward?

M. It is a Concession you can always force me to make.

CXXXIX. P. Keeping these Things in your Mind, consider next how many different Curves, or *Arches* (as you call them) a Stone, or any Projectile, may describe, by the attractive and projectile Forces acting together.

M. It may describe very many certainly. If I throw a Stone perpendicularly up, it falls back in the same Line or Track. If I give it a small Inclination to one Side, it describes *an high and narrow Arch*: If I give it a little more Inclination, it will describe *a lower, but wider Arch*; and so on. For I see there is no End of this Variety, so long as I can give it a different Inclination, and impress Force enough upon it, to make the Cast different.

P. Where the Strength of your Arm fails, you may take into your Supposition a Bomb, or Cannon-Ball, discharged from

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a Piece of Ordnance; or something as much above the Force of a Cannon-Ball, as that is above the Force of a Stone thrown by your Arm; or yet a Cause still more powerful than that, &c.

M. I see where this must end. The Difference is only in *more* or *less*, and the Reason the same, 'till we come to the Projection of a Planet by the Almighty Arm.

P. Not so fast: We are not there yet, — What if you throw a Stone neither upward nor downward, but straight forward, or in an horizontal Direction?

M. Only *one Side* of the *Arch* will be described; from the middle Point, or *Vertex*, to wit, which divides between the two Sides of the Curve.

P. What becomes of the other Side of the Arch?

M. That I cannot indeed tell. — But stay: There must be something under this Question. — If one standing on a lower Ground where the Stone fell, should so throw it back, that it returned to the Point from which I first projected it, with the same Force, so that it fell on a lower Place on the other Side of me; it would then describe both Sides of the Arch. Whence

I see, it described but the Part of a Curve, the whole of which it must have described in proper Circumstances.

P. I dare say, *Matho*, you have spoke better Sense than you are aware of.

M. It may be so; but shew me how?

P. Without staying to do that at present; are not both Sides of this Curve, from the vertical Point, equal and similarly bent?

M. Certainly, when in both Suppositions the Stone moves from that Point with equal Force, though to opposite Sides; It cannot perform the one half of its Course in one Path, and the other in another.

P. Imagine now you projected the Stone with an Inclination below the horizontal Direction; and tell me what must follow then?

M. It would describe only a *Piece of the Foot of the Arch*; the whole of which it would still describe backward, if returned with a proper Direction and Velocity.

P. It is so; the Curve would still be completed, *i. e.* it would still return upon itself, and be an entire Ellipsis, if it were not for some Obstacle the Projectile meets with.

M. That



M. That I do not see, for any Projectile of this Sort must still meet with the Earth, which stops its Motion.

P. You will see it gradually, by going on; and in the Interim you must keep in Mind likewise these several Particulars.

M. I shall not readily forget them, since I see the Reasons all along.

CXL. *P.* Suppose now, as you did in a former Case, that the Earth were perforated from us to the Antipodes, and that a Stone were thrown perpendicularly upward from the Center, with such Force, as to reach 20 Yards above the Surface on this Side; I desire to know how it would move after that?

M. It must fall back to the Center in the same Path, or straight Line, as much as a Stone thrown perpendicularly upward by my Hand, falls back on its own Track.

P. Would it stop at the Center?

M. It could not; for having (agreeable to the Maxim we spoke of) regained the Velocity in descending, which it lost in ascending; that is, the Velocity it was first projected with; it would rise 20 Yards above the opposite Surface, as necessarily as it did
on

on this Side. And because it could no more hang in the Air *there* than *here*, it would fall back to the Center again; and rise to us again; and (which is strange enough!) it would, I see, thus continue to move forward and backward for ever; acquiring still the same Force and Velocity at the Center, by which it would rise to the same Height here and there alternately. And still in equal Times; for the Space being the same, and the Efficacy of the Cause the same in equal Distances from the Center, the Effect would be the same in every Respect.

P. All this is right enough. But imagine now that the Stone is thrown up, not from the Center, but from a Point off to one Side of it, and in a Direction parallel to the former, so that it should still rise 20 Yards above the Surface; and in that Case how would it move?

M. You suppose now the Perforation so wide, that the Stone should have free Passage all the Way?

P. I do.

M. It would then rise to the Surface, with a small Degree of Inclination towards the Perpendicular (because now the projectile and attractive Forces do not act in the same Line)

Line) and crossing the Perpendicular at its Extremity, or the 20 Yards Height, it would fall back again to a Point as far on the other Side the Center, as that Point was whence it was first projected (for both Sides of its Path must be equal, and similarly bent) describing a very high and narrow Arch indeed! This is the same Case, differing only in *more* and *less* (as I said) as when I throw a Stone with a small Degree of Inclination, to the same Height, *viz.* of 20 Yards. And the two Curves should coincide about the *Vertex*, or in the Part above the Surface, if the Stone projected from below came up to the Point whence mine began to move, with the same Degree of Inclination.

P. You see then in this Case that your Stone describes but a Part of a Curve, the whole of which it would describe in proper Circumstances?

M. I begin in Truth to see a little into the whole Affair.

P. But should the Stone, when it falls back to the Point you mentioned on the opposite Side of the Center, rest there?

M. It could not; for (by Virtue of the *Maxim* still) regaining the same Force there, as when first projected, and having a similar Direction,

Direction, it should mount up to the opposite Surface, and describe the other End of the arched Figure, or Oval, *there*; as necessarily as it did the first End of it *here*. In a Word, for whatever Reason it described the first Half of the Ellipsis to our Side, for the same Reason it would describe the other Half of it to the opposite Side, or complete the whole Revolution. Nor could it stop then, but having the first Force still in that Point whence it was first projected, and the first Direction also, it must necessarily go through a *second* Revolution, and a *third*, and so on, without ceasing.

P. You have gone round with the whole Revolution, *Matbo*, so accurately, that you have left nothing to my Correction. I was particularly pleased to find you observe so opportunely, that when the two Forces, the *projectile* and *attractive*, act ever so little in different Directions, the Body could not move in a straight Line.

M. As they constantly urge the projected Body in new Directions, it must incessantly change Direction, or move in a Curve; tho' that Curve draws near to a straight Line; for I remembered that this was the Case where you said, the Ellipsis approaches to a straight

a straight Line on the one *Extreme*, as it may to a Circle on the *other*.

P. What are your Thoughts as to the *Time* of this Revolution?

M. Since the Body was projected with the Velocity to reach 20 Yards above the Surface, it must come to that Height in the same Time as if it had been projected from the Center. For I saw, from the Instance of the Body projected from the moving Plane, that the Effect of the one Force does not disturb the Effect of the other: The perpendicular Force raises the Body to the same Height, in the same Time, as if the Plane did not move; and the horizontal Force carries the Body the same Length and in the same Time, as if the Plane only moved; or as if there were no perpendicular Force.

P. I am glad you have got over this Difficulty, which was wont to give Beginners the greatest Trouble. But to return, If in any Point of this Ellipsis, the Stone were projected with the same Direction and Velocity, which it had in that Point, when it performed its first Revolution, will it not in this Case describe the same individual Ellipsis still?

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M. Certainly:

M. Certainly: It is this that makes the Necessity of its revolving constantly in the same Ellipsis, and that without End; because, to wit, it has the same Velocity and Direction in every individual Point, as it had there at first. Or, the Velocity and Direction in any one Point is necessarily connected with the Velocity and Direction in every other Point throughout the whole Ellipsis. Hence the Projection may be made from any Point, if with the Direction and Force proper to that Point.

P. Let not this Reasoning slip out of your Mind again.

M. I shall endeavour to remember it.—

P. But if the Stone were projected at a still greater Distance off to a Side from the Center, still in a parallel Direction to the perpendicular Projection, and with a Force to rise to the same Height; What must ensue?

M. It must describe a wider Ellipsis, but touching the former in the two *Vertices*; and the Time of the Revolution will be equal to that of the former. And the same Reasoning still holds, though the Distance of the Projection from the Center be supposed still greater and greater, the other Conditions

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ditions remaining the same. These Ellipses will all touch in the Vertices; their Times will be equal, and the first perpendicular Projection will be a common Diameter to them all. For there is no End, I see, of the Variety of these Ellipses, growing still wider and wider.

P. You see in this first Case then, how possible it is that a Body may describe an oblong or oval Figure, about a Center, by the Composition of two Forces, an attractive and a projectile?

M. I see, *Philon*, from this endless Variety of them, that I cannot throw a Stone in any Direction, but it must describe a Part of an Ellipsis, the whole of which it would describe about the Center of the Earth (if that were pervious;) and I can hardly find Words to express my Satisfaction and Surprise, to find that so common and childish an Experiment, as throwing a Stone out of one's Hand, should shew us the Truth of a Proposition, which sounds at first like an Impossibility. But upon Reflection, I see it must necessarily be so: It is this that makes a Stone, or any Projectile describe so regularly a Part of this Figure, *here*, at the *Antipodes*, or in any Part round the Earth. Is
short,

short, the *Action of Falling*, which you so warmly recommended to my Observation at our first Interview, contains in itself the whole Mystery of this Affair. The Body is always either falling, or rising by the Impetus it hath acquired in descending, till that be spent; and then it is in the Circumstance of descending anew.

CXLI. *P.* Let us stop here a little then, and look back: For it will not be amiss to observe, that when the Stone is supposed to be projected perpendicularly upward from the Center, it must perform its Course backward and forward, or run twice over the whole Diameter of the Earth, in an Hour and about 25 Minutes. And a Revolution in any one of those Ellipses, whether narrow or wide, will (as you rightly observed) take up precisely the same Time; till they become so wide, that the last of them coincides with a Circle at the Surface of the Earth.

M. You shewed me indeed a little before, that a Body must revolve at the Surface of the Earth in that Time; or performs 17 Revolutions in 24 Hours, that it may have a centrifugal Force equal to its Gravity.

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And now I see the Connexion, with Respect to the Equality of Time, all along through the intermediate Ellipses, 'till we come to the perpendicular Projection through the Center.

P. You have thus a right Notion of this Matter: But you will be still more surpris'd when I tell you, that, if a Body were projected from the Center but half way up to the Surface, or a 4th Part only, or an 8th Part, or even but a Mile; it would still take up the same Time (an Hour and 25 Minutes) to perform its Course forward and backward; or to perform a Revolution in an Ellipsis, or Circle, described on any of these different Heights as a Diameter.

M. Would a Body take as much Time to rise and fall through a Projection of a Mile's Height, as through one of 4000? Or to revolve in a Circle of 2 Miles Diameter, as in one of 8000 Miles Diameter?

P. Exactly the same Time, in this Case?

M. Shew me, I pray you, how this could be?

P. I shall endeavour to make you conceive it in some Measure, as it has Relation to what we are going to say. — First you must

must know, if a Body were placed within a hollow Sphere of attracting Matter, it would remain wherever it were placed, without moving to any Side. For though it were placed nearer to one Side of this hollow Sphere than to the other, the Matter attracting it on the opposite Side would be as the Square of its greater Distance: So that the Attraction increasing as much on account of the Matter, as it decreased on Account of the Distance, the Body would be in Equilibrium, wherever it were placed within the Sphere; or if it were set a moving, it would move on equably, without Acceleration.

M. This I think I have some Notion of; for if the Body were placed exactly in the Center, it could then move to no Side, being equally attracted to all Sides. And if it were removed from the Center, nearer to one Side, the Quantity of Matter it receded from, must be greater than the Quantity of Matter it approached to, and would therefore keep it in Suspense.

P. It is greater in the Proportion I mentioned, which admits of an easy Proof, if it were worth the while to leave what we are upon at present for the sake of that.

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M. You will shew me afterward where I may meet with this Proof; and in the mean Time please to go on.

P. If a Body then were placed on the Surface of the Earth, it would be attracted by all the Matter in the Globe: But if it were placed below the Surface (suppose a 1000 Miles) it could not be attracted by the Matter above that Height (for a 1000 Miles Thickness round about) more than if so much of the Globe were taken quite away.

M. I understand: The Body is, as if it were placed within a Crust of 1000 Miles Thickness, which could attract it no Way; or, it would only be affected by the Matter below that Depth.

P. And if it were 2000 Miles below the Surface, it could only be attracted by the remaining Matter of the Globe, and by none of the Matter within 2000 Miles of the Surface any where round.

M. This is but the same Case: I see, were the Body placed within a Mile of the Center, it would only be attracted, as if the Globe were but a Mile in Radius, all the Matter above that urging it no Way. But what follows from all this?

P. Where-

P. Wherefore in the perpendicular Descent of the Stone, the attractive Force you see is always as the Distance between it and the Center, or as the Space to be gone over. When the Space is twice as great, the accelerating Force is twice as great; when the Space is but a 4th Part, the Force is only a 4th Part. If the Space be but a Mile, or one 4000th Part, the Force will be exactly in that Proportion.

M. I am impatient for your Conclusion from this.

P. Whence, be the Space little or much, it must always be run over in the same Time; for twice the Space will be run over with twice the Celerity, in the same Time as half the Space with half the Celerity; or as a 4000th Part of the Space with a 4000th Part of the Celerity.

M. Let me consider this in my own Way.——

CXLII. When the attracting Globes are of equal Density, the Gravity on their Surfaces is as their Semi-diameters, or Distances from their Centers: Wherefore the Gravity to the Center, at any Depth in the Earth, must be as the Part of the Semi-diameter to

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be run over. Thus far is plain. — I divide the whole Semi-diameter into a certain Number of Parts, and the half of it into the same Number of Parts: Any Part in the first Division will be double any Part in the second Division; because the Whole is double the Whole. This likewise is plain, — The Attraction at the Surface, in the beginning of the Motion of two falling Bodies, is double the Attraction at half that Distance: Wherefore a Part of the first Division will be run over in the same Time as a Part of the second Division, though the one Part be double the other. — The upper Body has now double the Velocity of the under Body; it likewise receives a new Impulse of Gravity doubly stronger than what the other receives: This will cause the next Part in either Division to be run over in the same Time. It is so every where: The upper Body has always double the Velocity of the under Body, and receives every where a doubly stronger Impulse to increase it in that Proportion. — The Argument is the same, if I had supposed the lower Body to have but a third Part of the Semi-diameter to run over; the upper Body must in any Part of its Descent have had triple the

the Velocity of the *lower*, and every where have received a triply stronger Impulse, to maintain the Velocity in that Proportion. — Now, *Philon*, I am satisfied in this Particular with great Pleasure. A Stone, when projected but a Mile up from the Center, must take as much Time in returning to the Center again, as when projected four thousand Miles up, or to the very Surface.

P. This you have examined very minutely. You may likewise remember, when we were speaking of the various Laws of Attraction, which the *Creator* might have instituted in our System, we mentioned *that*, where the centripetal Force, or Gravity, was supposed to increase as the Distance from the Center of Attraction; and the centrifugal Force, in order to balance it, was also to be increased as the Distance.

M. I remember the Case distinctly.

P. But in the present Case you see the Attraction is increased as the Distance of the Stone from the Center of the Earth: Therefore if it were to revolve about the Center of the Earth in Circles at different Distances; *ex. gr.* so that the Radius of an exterior Circle should be twice the Radius of an interior; that it might have double the cen-

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trifugal Force in the exterior Circle, to balance the double centripetal Force, it must move with double the Celerity as in the interior Circle; and therefore perform a Revolution precisely in the same Time.

M. These were the very Conditions, and this the Conclusion the Matter was brought to: So that if this Law had obtained in the solar System, all the Planets (the uttermost *Saturn*, and the innermost *Mercury*) must have revolved about the Sun in the same Time exactly.

P. Hence therefore in the present Case, a Body would revolve about the Center of the Earth, in a Circle whose Radius were a Mile, or an hundred Miles, or a thousand Miles, &c. all in the same Time. viz. an Hour and 25 Minutes.

M. This is extremely obliging, to shew me these agreeable Speculations as we go along. —

P. To bring what we have said more within the Reach of being applied to our present Purpose, if we suppose that this were really the Law which obtained in the solar System —

M. Pray interrogate me on this Head, to see if I can give you proper Answers.

P. With

P. With all my Heart. If this then were really the Law which obtained in the solar System, and if two Planets revolved about the Sun, the one at 4 times the Distance of the other, in what Proportion should their Celerities be?

M. The Celerity of the *exterior* ought to be 4 times greater than the Celerity of the *interior*, to give it 4 times a greater centrifugal Force.

P. But if it were projected with more than 4 times the Celerity of the *interior*, what would ensue?

M. It could not then move in a circular Orbit, but would mount higher and describe an Ellipsis about the Sun, equal Portions of which would lie to opposite Sides of the Sun; just as the Stone did about the Center of the Earth; for the Law of Attraction is now by Supposition, the same in both Cases. As the Sun is placed in the Center of this Ellipsis, the revolving Body would be nearest him when in the Extremity of the lesser Axis. There it would move with the greatest Celerity, as the Stone did in moving by the Center of the Earth. In the Extremity of the greater Axis its Celerity would be least of all, that the *Areas described in equal Times* might

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might be equal: For thus it was with the Stone when it came up to the *Vertex* of its Curve.

P. What if the Planet were projected from the same Point with a still greater Celerity?

M. It would mount higher above the Sun, or describe a more oblong Ellipsis, which, as well as the former, would touch the circular Orbit in the Point of Projection, and in the Point opposite to that. And the same Reasoning holds, if we should suppose it projected still with a greater Degree of Celerity, from the same Point always: Nor is there any End of the Variety here.

P. But is there no Hazard, if the Velocity with which the Body is projected be very great, of its flying out through the celestial Spaces, without returning again?

M. None at all: Let the Planet rise ever so high, it must descend towards the Sun again, and describe the other half of the Ellipsis to the opposite Side; since by Supposition the centripetal Force becomes the stronger, the greater the Distance is.

P. What would happen if the Projection were made from another Point exterior to
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the former, and with a greater Celerity than what would be sufficient to make the Planet revolve in a Circle at that Distance?

M. It would describe Ellipses, still rising higher, the greater the projectile Celerity were supposed to be: All which Ellipses would have the Sun for their common Center. And this Argument is equally applicable to any Point we can name: Nor is there any End to the Variety of Nature, and Bounds of Possibility; that is to the Extent of Omnipotence, which soon swallows up the Imagination.

P. But what do you say as to the periodical Times in all these infinite Ellipses?

M. They would all be the same to a Minute. For if we suppose a Body to be projected perpendicularly up from the Sun to different Heights; since (as was said before, with Respect to the Center of the Earth) the accelerating Forces are always as the Distances to be run over; it must always fall back in equal Times, though one Distance should be a million of Times greater than another. And this is likewise true if these Distances be taken equal on the other Side of the Sun, or the several Lengths be made double. We have also just

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just now seen that Planets revolving at all possible Distances from the Sun must, on this Supposition, perform their Periods in equal Times. But a straight Line is the *extreme Ellipsis* on the decreasing Side, as a Circle is on the increasing; And when the Time in a straight Line, and a Circle on that as a Diameter, is the same, it must be the same intermediate Ellipsis, whether wide or narrow.

P. You see then it must be as natural for a Planet on this Supposition, to describe an elliptical Orbit about the Sun, as a circular one?

M. I see plainly the one is as natural as the other; which, notwithstanding, without this Deduction, I should have thought a strange Paradox.

CXLIII. P. After this, we have little more to do than to make the Transitions from one Law of Attraction to another: For if we next suppose that the Attraction is inversely as the Squares of the Distances from the Center of the Sun (which is the Law you know that really obtains) you will see the Deviations from the former

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Case to this, not at all unnatural, but such as in Reason they ought to be.

M. So far you shewed me before, that both the periodical Times and Celerities of Bodies revolving according to this Law are different from what they were in the last Supposition; the Squares of the periodical Times being as the Cubes of the Distances, and the Celerities inversely as the Square Roots of the Distances. It was thus that the *interior* of our two Moons had twice the Celerity of the *exterior*, which was at 4 Times the Distance, and but the 8th Part of her periodical Time.

P. These Proportions arose from bringing the centrifugal Force into an Equilibrium with the centripetal, in the present Law of Attraction: The Foundation of the next Difference will appear more obvious, which is this. A Planet in the former Case still returned toward the Sun again, though projected with a Velocity many Times greater than what was requisite to make it move in a circular Orbit at that Distance; because it met with the greater Resistance the higher it mounted. But it must be quite otherwise here, where the Attraction

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Attraction decreases, as the Squares of the Distances increase.

M. I am aware of this; for the Body meeting with such a hasty Decrease of Resistance as it rises, still feels the greater Facility in ascending; and this must necessarily have a very different Effect from the Case where it still found the greater Difficulty. In such Circumstances, it is possible, I conceive, if the Body were projected with a great Excess of Velocity, above what would make it move in a circular Orbit at any assigned Distance, that it should never turn down again, but move on towards the Region of the fixed Stars.

P. This is so possible, *Mathe*, that if it were thrown up but with twice the Celerity requisite to make it move in a Circle at the Point of Projection, it could never return towards the Sun, but run out through those Spaces endlessly.

M. That makes the impressing the projectile Force in this Case an Affair of great Delicacy! But what is the least Velocity, with which if a Body were projected, it could not descend again towards the Sun?

P. If the Velocity with which a Body would describe a Circle at the Point of Projection,

Projection, be as unit, or 1, by a Velocity as 1, 4142, &c. it should move in a Curve, which does not return upon itself, nor inclose Space, but runs out still to a greater Distance.

M. Then a Velocity, less than once and a half the circular Velocity, would throw the Planet quite off through the ambient Space?

P. It would. But if a Velocity as 1, 4142, would throw the Planet quite without the System, it must return if projected with any less Velocity.

M. I see it must, since the Velocity you name, is the least that could throw it quite off; however, at this Rate it may return from a prodigious Height; for there is hardly any fixing a Limit betwixt a boundless Space, and the next inferior bounded Figure: So that a Planet might ascend, I think, to as great a Height according to this Law of Attraction as the former, and still return again: Only a much more skilful and measured Force of Projection is required *here* than in the last Case.

P. You express the Difference of the Cases extremely well: The attempering a small Force (comparatively speaking) has the same Effect here as the Application of a vast

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a vast Force there. However let us suppose that a Body is projected with a Velocity a little greater than 1 only, or (that we may speak of something definite), with a Velocity as 1, 15; and since a Velocity as 1 would make the Planet revolve in a circular Orbit at that Distance, a Velocity as 1, 15 must carry it higher. And you will conceive the whole Matter the more easily perhaps, if you imagine that the Body moves, as it were, in a Medium *denser* nearer the Sun, but which becomes always *rarer*, as the Squares of the Distances, to which the Body rises, becomes greater.

M. This indeed afflicts me. The decrease of Resistance must have the same Effect upon the Motion of the Body, as a Medium growing rarer in the same Degree, though I otherwise see the Strength of your Argument: The Body must rise higher from the Point of Projection, or mount above the circular Orbit, because its Velocity is greater than 1; and yet it cannot fly quite off, because its Velocity is less than 1, 4142.

P. Suppose then, the Body being projected with a Velocity as 1, 15, that a Diameter to the circular Orbit is drawn from the
the

the Point of Projection, but produced indefinitely without that Orbit on the other Side; and then you will likewise see, that the Body thus projected, must come to cross that Line at some Height or other, on the opposite Side of the Sun: Or, at least, you will see some Objection, which hinders you from assenting to this.

M. I rather see the Necessity why it must be so; for I have the whole Scheme distinctly in my Imagination, and what you say shews me half the Ellipsis is already formed.—The projectile Direction at first was perpendicular to this Diameter; that is, the projectile and attracting Forces acted upon the Body at right Angles to each other: The Body, because of its greater Velocity, began immediately to move without the circular Orbit: The two Forces acted then obliquely upon it, which made it describe a Curve without the Circle: This Curve, since the Body could not fly off finally, must come to cross the produced Diameter again, in the opposite *Vertex*, to wit; for the Diameter goes through the Center of the Sun: And then the Body has performed half its Revolution. This extended Diameter becomes the greater

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Axis of the Ellipsis : The Body was at the nearest Distance to the Sun in the Point of Projection ; and is at the greatest Distance from him now in the other Extremity of the Axis. All the Time therefore from the Point of Projection to this Point, the Body has moved gradually with less Velocity, that the *Areas* it described in equal Times might be equal. Hence the projectile Force became more languid, as the Sun's attractive Force grew weaker. And these two Forces act now on the Body at right Angles again, in this remoter *Vertex*.

CXLIV. *P.* You have imagined the Case perfectly well, *Matbo*, and according to Nature. The slower the Body moves, the attracting Force hath the more Time to act : Therefore it bends the Curve all along, 'till at length it acts again on the Body at right Angles to the projectile Direction, and by that Means hath more Efficacy. But how doth the Body move from that remoter *Vertex* ?

M. Being now at its greatest Height, it begins to return ; and in descending its Velocity must be accelerated in the same Manner as it was retarded in ascending, by the

Maxim

Maxim we spoke of: For the Attraction to the central Body, which in its Rising hindered it, now conspires with it, and is equally strong in equal Distances. Hence it must describe the other half of the Ellipsis, similar and equal to the first, and in equal Times. For in returning, it comes as it were into a *denser Medium*, and feels a stronger Retraction to the Center, and that inversely as the Squares of the Distances; so that it cannot run out to an equal Height from the Sun on the other Side, as in the former Case; but returns to the Point from which it first set out, with the same Velocity, and in the same Direction. Whence it must perform a *second* Revolution, and a *third*, and so on without End, by the same Necessity as it performed the *first*.

P. You have prevented me here, *Mattho*, in making one material Observation, which is, that whereas in the last Case, equal Halves of the Ellipsis lay on opposite Sides of the Sun, here, on the contrary, the greater Half of the Ellipsis lies on one Side.

M. I saw it was impossible that two such contrary Laws of Attraction should

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have the same Effect. In the former Case the Attraction was least of all when the Body was nearest the Center; therefore the Body passed on almost in the Direction of the projectile Force, as the Stone did when moving in a narrow Ellipsis about the Center of the Earth. But *here* the Attraction is strongest of all, when the Body is nearest the Center: Therefore it cannot pass on, as in that Case, but must have its Direction most changed, or its Path most bent and incurvated in this Part. From hence I see the Truth of what you told me, *That the Deviations in this Case from the former, are such as in Nature and Reason they ought to be.*——With Respect to this a Thought occurs to me, which I believe I cannot well express to you, as it is yet but raw and undigested.

P. The Thought will come in View as you attempt to explain it.

M. If we suppose the Point of Projection to be the same, and the Velocity with which the Body is projected to be the same, in both these different Laws of Attraction; we shall more clearly see the Difference of the Effects, and the *Transition* from the one Case to the other.

P. I be-

P. I believe indeed we may; go on therefore to compare them.

M. Supposing then the Point of Projection and Velocity the same; in the last Case, because the Attraction is weakest nearest the Sun, that is, at the Point of Projection, the Body will move forward almost in the same Direction; or, if we may borrow the *Points of the Compass*, to denominate the Situation of the Ellipsis, it will lie from *South* to *North*, for instance; and the circular Orbit, which the Planet would describe at that Distance, will lie in the Middle of the Ellipsis; the Sun being in the common Center of both Curves. But in the present Case, because the attracting Force is strongest at the Point of Projection, where the Body is nearest the Sun, the Curve will be most bent there; and the Body instead of going on in the Direction of the first projectile Impression, will be strongly drawn about; so that this Ellipsis will lie cross the other, or extend from *East* to *West*. The greater Axis of this Ellipsis will coincide with the shorter Axis of the former, but reach a great Way farther: For the Body here will rise to a much greater Height, as having the same projectile

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projectile Velocity, and meeting with much less Resistance. Whence the present Ellipsis will be much larger, and the same circular Orbit at the Point of Projection, will lie in one End of it, touching it in the nearer *Vertex*: And the lower Focus of the Ellipsis, possessed by the Sun, will coincide with the Center of the Circle.

P. You have already attained a great Compass of Thought in these Matters, *Matho*, when you can pursue such a complicated Supposition with so much Justness and Propriety. This familiarly explains to us how, in the present Case, the Ellipsis must lie unequally to opposite Sides of the Sun, and leaves no Room for farther Doubt.

M. I am satisfied with this myself, because I understand what I say; which I confess is not always the Case.

P. To speak so as to understand one's self is no common Advantage; which we are not at all Times sufficiently aware of. But farther,

CXLV. Since you see the Necessity that the Body in this Case must return to the Point whence it was first projected, with the

the same Velocity and Direction which it had there at first, and for that Reason perform a second Revolution, and a third, &c. in the same Orbit; you will likewise see, if it were projected from any Point of the Ellipsis with the same Celerity and Direction, which it had in that Point in the first Revolution, that it must revolve in the same individual Orbit still?

M. I see the Necessity of this as much here as in the former Case; because getting the same Celerity and Direction in any Point is the same Thing, as if the Body had been projected from the *first Point*, or *nearer Vertex* of the Ellipsis, and so come up to that Point with the requisite Velocity and Direction. In short, this is none of the Particulars in which the two Cases differ.

P. In Order to describe, or move in this Ellipsis therefore, you see the Planet might have been projected with a great Variety of Celerities and Directions, according to the Point it was first projected from?

M. I see that in every Point from the *nearer Vertex*, whence we supposed the Projection made, to the *higher Vertex*, the

Celerity and Direction must have been different. For in the *lower Vertex* the Celerity was greatest, and the Direction of the projectile Force was at right Angles to that of the attracting Force: From that Point to the *upper Vertex*, the Velocity grew always less, and the Direction of the two Forces became more oblique, till the Attraction began to bend the Curve towards the other Extremity of the Axis. From this I see it was the Conveniency of the Supposition, and not Necessity, that determined you to imagine the Projection made from the *lower Vertex*.

P. Moreover, because the small triangular Spaces, or *Areas*, described in equal Times, must be equal, you will conceive that the Celerity of the revolving Body must always be inversely as its Distance from the central or attracting Body?

M. I conceive this easily; for equal Triangles have their Bases inversely as their Altitudes.

P. You likewise remember, when the revolving Body is at the Extremity of the *lesser Axis*, it is in the middle Distance between the greatest and the least?

M. I re-

M. I remember it; and that this middle Distance is equal to half the greater Axis.

P. The Body therefore at that Distance will have a mean Velocity between the greatest and the least?

M. It must; for since the Velocity decreases as the Distance is increased, when the Distance is half increased from the least to the greatest, the Velocity will be half decreased from the greatest to the least.

P. You express it very well. — But since the Velocity at the lower Vertex is greater than the Velocity in a Circle at that Distance from the Focus, and the Velocity in the upper Vertex is less than the Velocity in a Circle at that Distance, the mean Velocity will be equal to the circular Velocity at the middle Distance?

M. So it seems; for in passing from a Velocity greater than the circular, to a Velocity that is less, the Body at the middle Distance must move with a Velocity equal to the circular Velocity at that Distance.

P. Since then the Velocity at this Point is equal to the Velocity of a Body moving in a Circle at that Distance, and since the Description of Areas is equable to both in the

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the Ellipsis and Circle, the whole *Elliptical Area* will be run over by a *Ray* passing from the Body to the Focus, in the same Time as the whole Area of a Circle, whose Radius is equal to the mean Distance from the Focus.

M. I conceive it. The small triangular Area described in the Ellipsis, while the Velocity is equal to the Velocity in a Circle at that Distance, bears such Proportion to the whole *Elliptical Area*, as the small triangular Area, described in a Circle in the same Time, bears to the whole *circular Area*: And since these *like Parts* are described in equal Times, the whole Areas on each Side must be described in equal Times.

P. Therefore the periodical Times of a Body revolving in Ellipsis, and in a Circle at the middle Distance, that is, on half the greater Axis as a Radius, must be equal, or the same?

M. I see with much Pleasure it must be so. —

P. Lastly, from all this you will now observe, that when the Projection is made with a Velocity greater than 1, and less than 1, 4142, &c. it is as necessary that the

the Body should revolve about the Sun in such an elliptical Orbit, lying unequally to opposite Sides of the Sun; as that it should revolve about him in a circular Orbit, when the Velocity is as 1; and the Direction of the projectile Force at right Angles to the Direction of the attractive Force?

M. I see plainly the one Case is just as natural as the other, and follows as necessarily from the different Force, or Direction, in the first Projection. All that is thought unnatural in this Case disappears, when the Consequences of these different Conditions are rightly attended to.

P. This is all then you wanted to know; and I suppose by this Time you will allow, that we have spent more Time and Words upon it, than the Matter was worth; as I told you from the Beginning it would be.

CXLVI. *M.* Pardon me, *Philon*, I cannot allow any such thing. We have not yet discoursed an Hour upon the Subject, and now I see the Reasons of what before I thought an inexplicable Mystery; besides many entertaining Speculations which you have acquainted me with by the way. I have not thought the Time long. Or would you have had me,

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me, for the sake of not conversing an Hour with you, to remain ignorant of those things, perhaps for all my Life. If ever I come to apply more closely to such Matters, I hope I shall conceive them more readily, for having seen the natural Reasons of Things before hand: But if some unforeseen Accident should hinder my applying to them hereafter (which I hope and wish may not happen) I shall not at least, from an Hour thus spent, be quite ignorant of them. And why do you make such Haste? This is the last time I am to give you any Trouble.

P. I know of little more that can be said. You will easily collect by yourself, that there is no End of the Variety of Ellipses, which may be described according to this Law of Attraction, more than of those on the former Supposition: And there is a prodigious Difference also in the Degrees of their Eccentricity.

M. I saw before, that at whatever Distance we imagine a circular Orbit about the Sun, a Body might be so projected from any Point of it quite round, as to describe an Ellipsis, which should still rise to the opposite Side, and whose Plane should be the same

same with that of the circular Orbit; and that this Variety might be multiplied, as we supposed the circular Orbits to lie in different Planes: But I do not yet fully conceive what you mean by different Degrees of Eccentricity.

P. The Eccentricity, you know, is the Distance of either *Focus* from the Center; and you will easily conceive that the *Foci* may be still more and more distant from the Center, either when the middle Distance is enlarged, and the Ellipsis becomes greater; or when the middle Distance remains the same, and the Ellipsis is of the same Length, but varies in Breadth. In the first of these Suppositions there must be an inconceivable Variety, as we have already seen: For if the Velocity as 1,4142 would carry off the Body to an infinite Distance, by any less Velocity than that, the Orbit must return upon itself, and inclose Space, or make a bounded Figure. Hence the Velocity next less than that which would throw the Body quite off, must bring it back from an immense Height. This you yourself expressed very significantly before, when you said, *There was hardly any fixing a Limit between a boundless Space, and the next inferior bounded*

bounded Figure. And accordingly, some Bodies, which thus revolve about the Sun, are supposed to take not many fewer than six hundred Years to perform their Circuit.

M. This is astonishing! Such a Body must rise to an incredible Height; and have made but few Visits down to the Center of the System since the World began!

P. Between this greatest Height, and the least (the *lower Vertex* of the same Ellipsis, for Instance) where a Planet might revolve about the Sun in not many Days, there must be a vast Difference, and Room for many intermediate Orbits.

M. What must become of such a Body, if it should fly off?

P. Who can answer such a Question as this, *Matho*? It could not fly quite off by Chance, nor be without Design, if it did: But it is needless to spend Time in Things we know so little about. —

M. Please then to tell me what you mean by the other sort of Eccentricity, where the middle Distance remains the same?

P. It serves rather to acquaint you with the periodical Times of Bodies revolving in those eccentric Orbits, than that it really obtains in Nature.

M. It

M. It would give me the greater Pleasure to know a little about it on that very Account; though you have told me something already concerning their periodical Times. It is often necessary, I find, to suppose Conditions which do not obtain, that we may the more readily conceive what is real: Thus your shewing me on what Conditions a Body might describe an elliptick Orbit, about another in the *Center* of the Ellipsis, made me more easily understand how it might describe an Ellipsis about another in the *Focus*. And without that Help, I don't know whether you could have beat it into my Head.

P. Since the Ellipsis is described about two Points, as the Circle is about one; the *greater Axis* remaining the same, you may conceive these two Points (or the two *Foci*) to recede from each other, nearer the Extremities of *this Axis*, till they co-incide with these Extremities, and the Ellipsis becomes a *straight Line* on the one Hand; or to draw nearer one another, till they both co-incide with the Center, and the Ellipsis becomes a Circle on the other.

M. This I conceive without any Difficulty; because, as I told you, we have tried

to

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to draw the Figure all manner of ways; but how does it shew the periodical Times of Bodies revolving in such eccentrical Orbits?

CXLVII. *P.* You saw before that the periodical Time of a Body revolving in an Ellipsis, and in a Circle on the greater Semi-Axis, or middle Distance, as a Radius, is the same. Since therefore the middle Distance remains here unchanged, because the greater Axis is still the same, the periodical Times in the Circle, or extreme Ellipsis on the one Side, in all the intermediate Ellipses, and in the perpendicular Ascent and Descent through the *straight Line*, which is the extreme Ellipsis on the other Side, will still be equal among themselves.

M. This is curious and entertaining. And I see the Reasons we concluded from before, are still applicable, let the Ellipsis become as narrow as we can imagine it, till it at last really become a *straight Line*.

P. Now since the Squares of the Times are as the Cubes of the Distances, when the Bodies revolve in Circles; and since the Times in Ellipses, and in Circles on their greater Semi-Axes as Radii, are equal; the

Squares

Squares of the periodical Times will be as the Cubes of the middle Distances, as much when the Bodies revolve in Ellipses, as when they revolve in Circles, in which the middle Distance only remains, and the Eccentricity disappears.

M. This Regularity and Agreement is wonderfully remarkable: But what I most admire is the Times of the perpendicular Ascent and Descent. In the last Case, the perpendicular Projections, to what Height soever they rose, were still gone through in the same Time; because the Revolutions in all Circles, how unequal soever, were still performed in the same Time. And here the Times of perpendicular Projections observe the same Proportion with respect to their Heights, as the Times in circular Revolutions do with respect to their Distances.

P. You lay Things so well together in your Reflections, *Mathe*, that you often help both yourself and me to right Views of them. It is certain, Harmony and Proportion run through all the Works and Laws of Nature. —

M. If therefore two Bodies were thrown perpendicularly up from the Sun, the second 4 times higher, for Instance, than the first;

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the Time of its rising and falling back, would be to the Time of the Ascent and Descent of the other, as 8 to 1, that the Square of the Time 8 might be as the Cube of its Distance 4?

P. You are perfectly right.

M. By this Method, I presume, we might find out in what Time the Planets would fall from their present Heights, down to the Center of the System, if their Motions were stopt; of which I remember you spoke before.

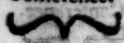
P. Very easily. The Time any Planet would take, to fall down to the Sun, if its projectile Force ceased, would be half the Time it would take to revolve at half its present Distance: Or the Time of both its rising and falling would be equal to a whole Revolution in a Circle at half the present Distance.

M. Give me Time to think of this; for I should have imagined, instead of falling in half the Time of a Revolution at half the present Distance, it must have taken a 4th Part of the Time in which it performs a Revolution at present, at the whole Distance.

P. Consider

P. Consider then which of the two it must be. —

M. If the Planet revolved at half the Distance, and if the *Foci* receded from the Center to the Extremities of the Axis, the Ellipsis would become *extreme*, or degenerate into a straight Line; and the Times both of revolving in the Ellipsis, and of rising and falling through the straight Line would be equal; for the middle Distance, or greater Semi-Axis remains the same: Their Halves therefore, or the Time of the perpendicular Descent in the straight Line, and revolving in the Semi-Ellipsis, or Semi-Circle, at the middle Distance, would be the same. — I see it must be so. — To suppose the Time of the perpendicular Descent to be the same as the 4th Part of the Time of a Revolution in a Circle at the whole Distance, is to suppose that the Ellipsis degenerates into a straight Line, and yet that the *Foci* still keep together in the Center, which is inconsistent: Or it is to suppose the Ellipsis, when contracted into a straight Line, to have the Sun, not in the *under Focus*, or extremity of the Line, but in the Center, or Middle of it.

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P. You correct your Mistake very ingeniously.

M. More depends, I perceive, on your Way of conceiving the Eccentricity to become *extreme*, than I was at first aware of.

P. You saw from your own Description of the Figure, that the only Way to make it narrower was by widening the Distance between the two Pins, or *Foci*, 'till they could get no farther asunder for the Length of the Cord or String.

M. It was so. — In order then to try this Calculation by myself, I first find out the periodical Time of the Planet at half the Distance, by the Proportion between the Squares of the Times and Cubes of the Distances; and Half of that will be the Time of its falling directly down to the Sun, from its present Distance?

P. Or the Whole of it will be the Time both of the Ascent and Descent through that Height. — Now, to conclude, *Matbo*, from all this you will see, though the Earth and the rest of the Planets revolve about the Sun in Orbits somewhat eccentrical, this no way disturbs the Proportion between their periodical Times and the Cubes of their middle Distances. The Earth is farther from

from the Sun in the Summer, than in the Winter : For from the *vernal Equinox* to the *autumnal*, is about 8 Days longer, than from the *autumnal* to the *vernal*, because the greater half of the Ellipsis is then to be run over ; and about the Summer Solstice the Sun's Diameter appears somewhat less, he being then farther Distant from us : And for all that we are not otherwise sensible of this, with Respect to Light or Heat : Our Heat particularly holds no Proportion with the Sun's Distance.

M. I am as glad now to know these Things, as I was before afraid, lest they might have disturbed what I already knew. From hence I perceive that it is manifestly a Work of Contrivance and Design, that the Planets should revolve in Orbits so nearly circular. The Circle is but one of the innumerable Kinds of Ellipses : And it is perfectly wonderful that so many Bodies should be determined to this particular Species, when it was as natural and easy to revolve in any one of ten thousand others.

CXLVIII. But you seem to insinuate that there are different Bodies, which revolve
X 3 about



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about the Sun in those eccentrical Orbits, and ascend to a vast Distance from him.

P. Those Bodies are indeed reckoned to be considerably more numerous than the Planets themselves, either primary or secondary; and are now allowed to belong equally to our solar System. They revolve, you see, by the same Forces impressed, and observe the same Proportions in their Motions, as the Planets do. Some of their Periods seem already to be determined with a good Degree of Probability: But more of them are still uncertain. This is a Subject for the Industry of future Ages. Those *Comets* (for so they are called) do not move according to the Order of the Signs, or from *West* to *East*, as the Planets do; but often directly contrary: Nor do they revolve in the same Plane with the Planets, nor in the same common Plane among themselves; but move through the System all manner of ways: For this depends on their first Projection. Consequently their *Aphelia*, or the remotest Part of their Orbits, lie indifferently to all Parts of the Heavens. They all rise above the Orbit of *Saturn*; but some of them mount to a prodigious Height between that and the fixed Stars. Thus *that Comet*, whose periodical

periodical Time is reckoned to be 575 Years, rises to about 14 times the Distance of *Saturn* from the Sun; which is an amazing Height, if we consider it in itself, and not as it is expressed in this small Number.

M. How is this found out?

P. Having the periodical Time and Distance of *Saturn* (or of any of the Planets) and the periodical Time of this Body, by the Proportion we have so often mentioned, between the Squares of the Times and Cubes of the Distances, you may easily find out its middle Distance, or half the larger Axis of its Orbit.

M. I remember it: We thus find out the Distance proportional to any Time, or the Time proportional to any Distance.— And this at last discovers to me the Meaning of the Particulars concerning which I asked you in the Beginning of our last Conference. The *Upward* and *Downward* with respect to the Sun, I see, or his Attraction, reaches far above the Orb of *Saturn*; since it extends to a Distance 14 times wider than the whole Planetary System. O! were it allowed us to find out what passes there!

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P. Your Wish is preposterous at present. The Knowledge of some Things is as wisely denied us, as the Knowledge of others is indulged to us.

M. Well.——It also now appears wisely disposed, that all the Planets should move in, or nearly in the same Plane; since other Bodies were to roam through the System all manner of ways: For thus, I suppose, their interfering, or dashing against each other is prevented.

P. It is certain, *Matho*, since *God* presides over all Nature, that nothing can be ordered as it is, without a wise Design. The *dismal Catastrophe* you mention is wisely prevented and perhaps by this Means. To suppose that such fatal Shocks in Nature may casually happen, or that the Planets may be liable to Decays and Dilapidations, is not, in my Opinion, right Philosophy; but looks as if we imagined Matter were governed by a *blind Power*.

M. I come entirely into your Sentiments on this Head: But pray what is the Use and Design of those wonderful Bodies, which move thus through the System, in a Manner peculiar to themselves? Are they habitable? Why approach they so near the Sun? and then

then run out to such an unmeasurable Distance from him? Can there be such Bodies in other Systems? Or is ours singular?

P. You touch upon another signal Instance, where we ought humbly to adore and reverence a Knowledge superior to our own, even in those Things, the Use of which we are quite ignorant of.

M. And for all that I have heard *Comets* spoke of in Conversation, with a certain Dread and Horror.

P. That is the Thing: They rarely visit us, or rather the gross of Mankind rarely observe them; therefore their Appearance has been thought ominous. Formerly they were imagined to forebode some great Disaster, or general Calamity to the Inhabitants of the Earth: And lately they have been thought to be designed for bringing about great and fatal Changes to the Earth itself, by Deluges and Conflagrations. And certainly, when beheld through the Telescope, they make a frightful Appearance, with long blazing Tails, and something like fiery Hair about the *Nucleus*, or Star itself. Others think they serve to recruit the Expence of the Sun and Planets, which without such Reparations must waste and become at last useless.

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less. Others think this Expedient forced and unnatural, that a greater Number of Bodies should only serve to repair the Decays of a smaller. And in Truth, all these Conjectures shew rather *that natural Impatience*, which is planted in the Mind of Man, of being ignorant, than their Ability, to find out the true Reasons of Things.

M. How various and wonderful are the Works of God! This is a new and tremendous Scene! It is not indeed without Reason that you say, we ought to adore and reverence a Knowledge superior to our own, even in those Things whose Use and Nature we cannot so much as guess at. How dreadful is the Power of that *Almighty Arm*, which so projects these unknown Bodies that they pass without the Limits of our World;—with such measured Force, that they return from thence, instead of flying off to other Regions of the Universe;—— with such Direction and Skill, that they do not dash against the Planets, and bear down the habitable Globes of our System! How far are we from the full Knowledge of Things! Or can our Desires of Knowledge ever be satisfied? Why are they so strong and natural, if the satisfying of them be impossible?—

You

You say *they are preposterous at present*: When will they be proper? — after we are dead? You own *there is a natural Impatience planted in the Soul of Man.*

P. The Sentiments of Reverence, *Mathe*, which the Subject we speak of excites in you, seem to me just, and becoming; tho' your Expostulations are somewhat warm. But are you not afraid lest they expose you to the Raillery of your *Equals*?

M. Why should they expose me?

P. Those, whom Birth and Fortune have raised above the inferior Crowd, laugh at these Things.

M. What is it then they are serious about?

P. *Hounds, Horses, Dress, Diversions*; and in Time, *Drinking, Gaming, &c. &c.*

M. I find I have no Turn for these great Exploits, and must be content with a less Share of Reputation than they afford. — But with Respect to the Subject we are speaking of, could you bear the Importunity of two or three Questions, for my Satisfaction, before I take my Leave of you?

P. Much more easily, I am afraid, than I could answer them.

CXLIX. *M.* In the first Place then, as preparatory to what I want to know, tell me wherein a material System aids and assists the Soul to *know* and *understand*?

P. Instead of two or three Questions, you seem to begin a new and laborious Subject, which we have not now Time to discourse upon at due Length.

M. Do not fear; I shall bring my Questions within a narrow Compass.

P. You have Principles whereby you may satisfy yourself in this Affair, if you call to Mind what we said before, concerning the sluggish and inactive Nature of Matter. A material System is made consistent with a Degree of Life and Activity, by a wonderful Instance of Divine Power; but can no Way bestow Life or Activity, or any Degree of them, upon the Soul. When we examined Matter in all Views, we found it utterly incapable of ever becoming a self-moving Substance, even by *any Power*. To ask if the Deity could make it *such*, was to ask if he could perform a Contradiction. Such a Thing is not the Object of any Power. It is joining together inconsistent Ideas in the Brain of Man; or rather joining together

Words

Words in his Language, which express inconsistent Ideas: Such Ideas cannot be joined. Hence Matter is a *resisting impeding Substance*, as it is a solid extended Substance. Consider how deep these Things go. —

We know not, nor can we name a greater Absurdity, than that *Union* to a dead and torpid Substance should give the Soul Life and Power, or any Degree of them; or that *Separation* should again deprive it of these. The Soul therefore must be percipient and active in its own Nature, independent of Matter — Examine in your own Mind, if this be saying any more, than that a *living Being cannot owe its Life to Inertia and Deadness*.

M. It is satisfactory enough.

P. Farther, *Matbo*; Matter, when best disposed, must limit the Power and Activity of the Soul: And when disordered or indisposed, may quite obstruct or impede its Operations; but can in no Manner *aid*, or *assist* its Power and Energy, otherwise than by *confining*, and *determining* them to one Manner of Exertion. Hence the Soul, when separated from Matter, must be freed from Indisposition, and have the Confinement taken off from its natural Activity.

M. That

M. That is delightful!

P. And certain also, since the *Soul* is a living Being, and the *material Frame* a dead Substance, liable to Disorder. Such a Frame at best, can do no more than be instrumental in a limited Degree; and when the Parts of it are disordered, the living Being languishes still under greater Confinement. From hence proceed those many equivocal Appearances, which we understand so ill, and reason so falsely upon. The *Soul* suffers from the Union, and has the Disorders of the Frame imputed to it; while Matter is exalted above itself, in being made instrumental to the Activity of the *Soul*. Upon this Account we ascribe the Life of the *Soul* to nothing so much as to Matter, or rather to nothing but Matter; and every Shock of the material System alarms us. They who seek a Name from Paradox and Novelty, take the Advantage of our ignorant Concessions, fortify our Fears, instead of unravelling the Subject, and triumph in the universal Loss of Being, which they threaten to Mankind. Whereas, would we distinguish carefully in our Reasonings, between two such opposite Natures, it would be easy to dis-

point

point them. For, as I said, the great Instance of Almighty Power is, that the Soul lives and perceives in Conjunction with Matter, and not that it should live, perceive and act, when separated from *that*. What we see should remove our doubt; the great Difficulty is already performed: Every Act and Perception of the Soul, in a State of Union, is a firm and certain Proof, though but a faint Specimen, of the active and percipient Nature of the Soul, when existing by itself, and freed from the Limitation of a dead Substance. In short, consider Matter as it is in all the Universe beside, as it is in a Stone, as it is in the Herb of the Field; the same it is in the Body of Man, the wonderful Workmanship only excepted.

M. You have said enough, *Philon*: I call to Mind all the Particulars you shewed me at large before, concerning the inert Nature of Matter. Its very Sluggishness and Passivity supposes the Power of the Deity constantly exerted in every Effect it is thought to perform. So little can it impart Life and Activity to any other Thing! I am much pleased in this respect, that we considered the Nature of Matter so narrowly, and on all Sides.
My

My Conviction was then, and is still without any remaining Scruple. And now I see, that every Conclusion we then made was an Argument for the self-sufficient Nature of the Soul; in Opposition, I mean, to its subsisting by the Help of Matter, or owing any Perfection to, or borrowing Power from that dead Substance. — One Thing more with Respect to this, which you may answer in two Words, and I have done. What do you mean by those *who seek a Name from Paradox and Novelty*?

P. In two Words, the Mortality of the Soul is but an upstart Notion, when compared with the Knowledge of its immortal and unperishing Nature, which is as ancient in the World, as the Creation of the very first Man: Nor was it called in Question for a long Series of Ages (I might tell you near the very Olympiad), when Men began to affect a new Reputation of Learning, from maintaining what was never heard of before. Then at length the Existence of the Deity and Immortality of the Soul began to be disputed.

M. You mean that these two Truths were immediately revealed by the Creator himself to the first Man?

P. I do;

P. I do; and this is as certain as any Truth in Philosophy.

M. I remember something you cursorily hinted concerning the Creation, in our last Discourse. — But might not these Notions have been again forgot, or fallen into Oblivion?

P. They never could be forgot by such a dependent Creature as Man. They might in Length of Time be disguised by idle Fables, or human Inventions superadded, (as indeed happened), but it is impossible they could ever wear into Disuse, or be lost; there are so frequent and so many Occasions to call them to mind, in Life, and in Death. The Indefeasibleness of these two Principles is owned, or rather clearly proved, by some Authors, who notwithstanding contend that there are whole Nations of original Atheists, without any Notion of, or Name for a *Supreme Being*: So that you may easily allow, it cannot be denied.

M. I begin to see the Reasons why such Notions, once broached in the World, must be conveyed down to all Posterity. But then if it be certain that they were revealed to the first Man, it is hard to conceive that

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there should be any where a Nation of Atheists : For all Men must have descended from him, and these Notions have been propagated together with the Species.

P. You have Reason so to say. Atheism and Irreligion is not the Vice of Ignorance, but of misapplied Knowledge. * And that there should be whole Nations of original Atheists is contrary to the Reason and Nature of Things ; unless we will suppose that Men at first grew out of the Ground, in different Parts of the Earth, some upon the Banks of the *Tanais*, and others among the Flags of the *Nile*.

M. You bring to my Mind the old Dispute between the *Scythians* and *Ægyptians*. — These short Hints you have now suggested, I must consider by myself hereafter ; but to come to the Particulars I principally intended, tell me

CL. Is it possible that a Man might not be delighted with the Knowledge and Contemplation of the Works of Nature, which we have been discoursing about ?

* See *Ælian's* various History, Book II. Chap. 31. *Οἱ μὲν τῶν Βαρβάρων ἄθεοι.*

P. It is directly impossible that a rational Being could be indifferent, or unconcerned about them. We are carried by Reason itself, the commanding Part of our Nature, to the Admiration and Study of those Works. A natural Curiosity, no Footsteps of which is to be seen among the inferior Creatures, at first engages us, (so artfully are they contrived to catch the Soul with Wonder!) and this is soon improved into a rational Pleasure. And since they are the Works of the Deity, by how much the more we see the Power and Wisdom displayed in them, so much the more must we admire and reverence their Author. But farther, they were set forth purely with this very Design; for you saw before, *That all Things were made for the Sake of rational Beings.*

M. It is incontestable that what is of less Dignity, must always be referred to the Use of that which is more noble; and Reason is the highest Perfection among Creatures.

P. He therefore, who has not a Taste for this rational Pleasure, must have his Mind pre-occupied, and engaged in lower Pursuits.

MATHO: or, The

M. And he, who follows the Dictates of Reason, must always wish for a more perfect Knowledge of the Works of Nature?

P. Certainly: Insomuch that he cannot disengage himself from this Desire, otherwise than by first enslaving his Reason, and making it subservient to inferior Views.

M. Will this endless Desire of Knowledge be always satisfied?

P. Put the Question thus, *Matho; Will God, who is the supreme Reason, ultimately gratify the rational Desires of his Creatures?* and then try if you can doubt of it.

M. Hence then the Soul must not only be immortal, but endlessly happy?

P. And endlessly advancing in Happiness also; still going forward in the Improvement of its Nature, and the Knowledge of the Perfections of its Creator. Whence (if I might use the Expression) the Relation between the Deity and the rational Soul still becomes stronger. For it is altogether contrary to the *Eternal Reason* (which Truth you ought to have strongly imprinted on your Mind, as a Cure against the Fear of Death, and a Comfort in the Miseries of Life;) it is, I say, altogether
contrary

contrary to the *Eternal Reason*, that by how much the more perfect the rational Soul becomes, it should be so much the nearer to becoming nothing. Which Absurdity must nevertheless take Place, if it were ever to have an End. Hence the longer it lives, the less it can die.

M. O! pleasing Truth! Happy Condition of the rational Nature!

P. Suppose, *Matbo*, for a skilful Artist does nothing rashly, designs nothing in vain; suppose that the Deity, through all the Lapse of past Ages, has supported the Universe by such Miracles of Power and Wisdom, only that he might at last please himself, with letting it fall to Pieces, and enjoy the Spectacle of the Fabrick lying in Ruins.

M. Can I harbour such a Thought of the Deity! Or suppose this a Design worthy of infinite Wisdom!

P. Suppose at least, that the Deity will utterly cut off *that Nature*, for whose Sake he created the Universe; the material Fabrick itself still remaining.

M. This is still more against the Nature of that Being, who is the *Eternal Reason* to abolish the rational Part of his Works, and cherish a Heap of Matter!

MATHO: or, The

P. Can there then be a greater or stronger Security for the Immortality of the Soul, than the *immutable* Nature of the Deity?

M. I see, *Philon*; I see the happy Condition of the rational Nature! Eternal Reason that cannot yield to Time or Accident, to Sicknes or Death, and the *Divine Nature* that cannot change, are the firm Pledges of its Immortality! You have made me as secure, as if I were already among the *Blessed*, and in the Possession of Joys beyond the Grave. This is the only *Amulet* against the Fears of Death, and Evils of Life. The Nature of the Soul, and the Design of the Deity in creating it such now appears.

CLI. *P.* Let those Men consider this, *Matbo*, who are such zealous Partisans for the Mortality of the Soul.

M. It surprises me much that any Man should shew his Zeal in defending such a Notion, or be so much an Enemy to himself as seriously to wish it true.

P. You may soon meet with such Books where the Notion is defended.

M. I should hardly think them worth the Perusal; for it seems to me a direct Contradiction

tradiction that any Man should be in love with *being Nothing*, because then he could have no Desire remaining for any Thing else. It is, I think, in Consequence of our Love of Existence, that we desire any other Thing whatever, that we wish one Thing rather than another, and consult our Reputation even after Death. Why should a Man who wishes to be nothing care for what might happen, or for what might not happen, hereafter? Or even before? He can have no Interest in any Events, provided he be cancelled out of Nature. The only consistent Action he could go about, were immediately to put an End to his Life, and do all in his Power to get rid of *Being*. In short, as Things appear to me, the Desire of Existence is the Foundation of all our other Desires, and of all our *Endeavours*: Otherwise let me see what it is a Man should wish or struggle for, who wishes to have no Relation with Beings, or their Actions; or any Thing in Existence? To wish that the Relation with Things existent should continue, and to lose Existence at the same Time, is repugnant.

P. You shew extremely well, *Matbo*, not only the shameful Falshood that lurks

in the Soul of a Man, who shews a Zeal in propagating this Notion ; but the express Contradiction that a Man should be concerned for any Thing, whose greatest Concern it is that he himself should be nothing. The greatest Concern, I say ; for if any other Concern could be greater, that must be for Things in Existence : Non-existence has no Concern belonging to it. And if he had a greater Concern about Things in Existence, he must, by the Excess of his two Desires, wish to exist himself, that he might contribute his Endeavours, or participate the Pleasure of the Success. You remember the last desperate Comfort of the *Carthaginian Queen* ; *Omnibus umbra locis adero* ; — No Man ever wished to be totally extinguished in Death, who had any Concern about posthumous Events.

M. I remember likewise the Story, how the Shame of being exposed naked after Death hindered the *Milesian Virgins*, I think, from putting an End to their Lives, when nothing else could. Nor can I conceive how any Person could throw aside all Concern for his posthumous Reputation. Which shews, not only that he does not wish, but that he does not suppose he shall

shall be quite extinguished in Death. And though it should be said, that this is but a groundless Prejudice which Men fall into, yet it shews that the Desire of being always *Something*, and the Presumption that we shall always be *Something*, is so much the stronger.

P. The Disingenuity of these Men's Zeal appears also from thence, *Matbo*, that Non-existence is really nothing, and so cannot in the Nature of Things be the Object of Desire: All the Objects of Desire lie clearly on the other Side. It may be said, it can as little be the Object of Aversion; but the Good it would deprive us of makes it as much the Object of Aversion, as a *real Evil* can be.

M. The Consequence is plain.

P. Since therefore we can only desire *Something real*, that is, Existence and Pleasure; since this is the Law of our Nature, and equal to a physical Necessity; we cannot be so constituted by the Author of our Nature, as necessarily to desire one Thing, and be designed for another, which is the direct contrary of it. Had we no Desires at all, or rather were we cloyed with Existence and disgusted with Happiness, that
would

MATHO: or, The

would shew that we were designed for utter Extinction: But it is repugnant that Happiness should be disgusting, or other than the Object of Desire.

M. From what you say it seems to follow (and I see it must), that Misery and Pain are the only Objects of Aversion in the Nature of Things.

P. You are very right: And from this again it will likewise follow, that they only, who fear the bad Consequences of a mis-spent Life, can wish for a total Death. And this, when you have examined Things on all Sides, you will find to be the only Case wherein it is possible to wish to be utterly cut off: But it is in vain; the Law of our Nature is as immutable as Fate. Punishment is as unavoidable in the one Case, as Happiness is certain in the other. — This likewise is possible (so perverse is Man!) that some may strongly contend for the Mortality of the Soul, out of Vain-Glory; though at the same Time their Nature shrinks back at the serious Thoughts of it. And though some should push this Affectation so far as to make it a Point of Honour, to appear constant to the last, for Fear of bringing a Disrepute upon their Character,

Character, or their Principle (as is reported of the famous Atheist *Spinoza*;) yet this shews the Inconsistency of their Thoughts, or rather the Perverseness and Disingenuity of their Hearts, to pretend a Concern for their Reputation, and a Fondness of being nothing at the same Time. So that there is nothing but Perverseness and Contradiction on this whole Side of the Question.

M. Those Men, I think, affect the Reputation of *Parricides*, or of a Crime for which Language has not a Name; who place their Zeal in shewing that the rational Soul must be cut off, and that there is not a Deity to govern the World. If this were Matter of Triumph to them, what is it that could be Matter of Grief and Dejection!

CLII. P. On the other Hand, *Mattho*, we might observe that, as it draws near to the brute and unthinking Nature, not to desire the Continuation of Existence, so the greatest, the best and most virtuous among Men have shewn the most ardent Desire for the Immortality of the Soul. This is the Spring of all the virtuous Actions in Life. No Man ever died in the Cause of Virtue and Liberty, for the Sake of Truth, in Defence

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fence of his Country, or on the Account of Posterity; who had not Immortality in some Sense or other before his Eyes. Cicero says, *Nemo unquam sine magna spe immortalitatis pro patria offerret ad mortem.* He observes that *Themistocles, Epaminondas*, all the great Men of Antiquity, and he himself, needed have given themselves no Trouble for the Sake of the Commonwealth; but adds, — *Sed nescio quomodo inhæret in mentibus quasi sæculorum quoddam augurium futurorum; idque in maximis ingeniis, altissimisque animis, & existit maxime, & apparet facillime: Quo quidem dempto, quis tam esset amens, qui semper in laboribus, & periculis viveret?* Why do we so studiously provide for our Children, but because we think the Relation between us and them is to last after Death, interminately? No Man fixes a Period to his Views in this Case. We endeavour by great and noble Actions to deserve well of our Country; not because we wish soon to be cut off from the Nature of Things; that would be the Source of *Indifference*, of *Neglect*, of *Selfishness*; but because we presume we shall some Way or other still have an Interest in the Welfare and Prosperity of the Survivors. It is from

from this secret Spring that the Legislator invents and digests such a System of Laws, as he thinks may be eternal. He adopts the whole Common-wealth for his Offspring, and upon that Account never proposes an End of the Relation between him and them, more than a Parent does with Respect to his Children. He provides as far as human Foresight can, a Remedy against every Emergence or Accident which he fears might prove fatal to the Community; and figures to himself, in the secret Workings of his Mind, their thriving and flourishing in Ages to come, without any Bounds to the pleasing Prospect *. — I need not pursue this Subject farther for you, *Matbo*, your own future Observation will

* These several Notions will be allowed to be more authentick, when it is known they are *Cicero's*. His Words are, — Maximum verò argumentum est, naturam ipsam de immortalitate animorum tacitam judicare, quòd omnibus curæ sunt, & maximè quidem, quæ post mortem futura sunt. Serit arbores, quæ alteri sæculo prosint, — quid spectans, nisi etiam postera sæcula ad se pertinere? Ergo arbores seret diligens agricola, quarum aspiciet baccam ipse numquam. Vir magnus leges, instituta, rempublicam conferet. Quid procreatio liberorum, quid propagatio nominis, quid adoptiones filiorum, quid testamentorum diligentia, quid ipsa sepulchrorum monumenta, quid elogia significant, nisi nos futura etiam cogitare. *Tuscul. Quæst. Lib. 1.*

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shew you, that the Desire of Immortality, in some Sense or other, is the Source of every great, every brave, and gallant Action among Men. Read ancient History, consider the present Times, look into the Works of the Learned, fix your Eyes on all the greatest Examples, on every the most conspicuous Person; you will find all full of this Spirit, and arising from this Desire.

M. What you say gives me a different Prospect of Things from what I had before. I begin to see that the Desire of Immortality in some Shape or other, or perhaps under some Disguise, is the great *Principle* that animates human Life: Or rather I ought to have seen it before, when I saw that the Desire of Existence is the Foundation of all our other Desires, and of all our Endeavours. Hence the *lowest*, as well as the *greatest*, among Men, are constantly pushed on by this Principle; since all the Provision that is made for Life, is plainly an Endeavour for the Continuation of Existence, and not with a View to put an End to *Being*.

P. The Observation is very just. The Principle of Self-Preservation always works for the Continuation of Existence, and in

a reflecting Being formally extends to the Desire of Immortality; which therefore cannot be found in the brute Nature. This Desire may often degenerate into a Vice, as when we think we can never make Provision enough for the sensitive Part of our Nature: It is then under a Disguise, but still it is at the Bottom. The Desire is still good in itself, and necessary to our Nature: But Reason then is made the Slave of Sense, and perhaps the Instrument of Vice. In short, *Matbo*, This original Desire shoots out into a thousand different Forms of Action: In the ordinary Efforts of Life it is less taken Notice of, because every one pursues the same Track; but where it strikes out of the common Road, it becomes remarkable. Consider how many different Ways Men have taken to preserve their Memory when gone. Every one who has Power, or Money, or Genius, falls on some Means or other, to inform Posterity, that such a Person once existed. — *Et quantum nobis denegatur diu vivere* (says *Pliny* the younger) *relinquamus aliquid, quo nos vixisse testemur.*

M. It is so; Men have contrived some Sort of a Way to survive themselves in Brasses and

and Marble; in Books, Buildings, Monuments, Pyramids, Pictures, Pillars, Inscriptions, and many more Ways than I can name. What would not Men give for Existence itself, when they endeavour to preserve the bare Memory of having existed with their utmost Industry! For it is certain that all Desire of posthumous Praise and Reputation proceeds from a Desire of posthumous Existence, if I might use such an Expression.

P. And in this Respect, those very Men who boast the Happiness of being utterly cut off, shew themselves equally industrious with others; whereby their Candor and Ingenuity may be judged of*. The Atheist is formed in Opposition to his own Principles: He burns with a Desire of posthu-

* Thus *Lucretius*,
 Avia Pieridum peragro loca, nullius ante
 Trita solo; juvat integros accedere fonteis;
 Atque haurire: Juvatque novos decerpere flores,
 Insignemque meo capiti petere inde coronam,
 Unde prius nulli velârint tempora Musæ.
 Primum quod magnis doceo de rebus; & arctis
 Religionum animos nodis exsolvere pergo:
 Deinde, quod obscurâ de re tam lucida pango
 Carmina, Musæo contingens cuncta lepore.
Lib. 4. Ver. 1. The Author here builds his immortal Fame on the Doctrine of Annihilation!

mous Praise, as well as present Admiration: He writes, disputes, propagates his Principles: He cannot divest himself of the Desire of Existence: No Man ever got above that Desire, except in the particular Case I mentioned to you. Therefore it is a fallacious Argument in a late famous Apologist for Atheism, to tell us how many great and learned Men have been Atheists*. Were it so, their Learning could be no Plea for their Principles; more than this Author's is for the Defence he makes for them: But in Truth Learning and Knowledge never made a Man an Atheist, nor never will.

* Mr. Bayle, when he would shew us how considerable Atheism is, says — *Que si, sans répéter tous les exemples que j'ai déjà rapportez ou dans mes Pensées Diverses, ou dans mon Dictionnaire, je vous nomme seulement quelques-uns des modernes, que l'on accuse d'Atheisme, un Averroes, un Calderinus, un Politien, un Pomponace, un Pierre Bembus, un Leon Dixième, un Cardan, un Cesalpin, un Taurellus, un Cremonin, un Berigard, un Viviani, un Thomas Hobbes; pourrez-vous croire avec le Pere Rapin qu'il n'y a qu'un petit Auteur de sonnet ou de madrigal, qu'un Debauché, qu'un Courtisan, & qu'on femme galante qui soient susceptibles de l'irreligion? Peut-on caracteriser ainsi les Philosophes, les Medicines, les Mathematiciens, les Humanistes les plus celebres? Continuat. Des Pens. Divers. §. 18.* It could never recommend Avarice, or any Vice, to tell what Numbers had been addicted to it.

It is an easy Thing to doubt, or deny; and it is Ignorance only of *Nature* can make a Man do either in this Case.

CLIII. *M.* From what we have said it easily appears what the World would come to, without this enlivening Principle.

P. The Affairs of Men could not then long subsist. Had they a contrary Desire, every one would instantly rush upon Death as the likeliest Means to get out of *Being*: And there must be an End of the Species at once. Or, had they no contrary Desire, but an Indifference whether they existed or not, whether they were *something* or *nothing*, all the Endeavours in Life must instantly stagnate, and in a little Time utterly cease. No Man would act without a Motive of Action, having nothing desirable, nothing worth while, to put him upon exerting his Powers. If the Continuance of Existence were not a Motive (as you said before) nothing else in Nature could.

M. This affords us a compendious View of what we saw before only in Parts; namely, That this Desire of Existence is the only Spring of all the Industry in Life; and

and therefore not only of what we do for ourselves, but of the generous Actions we do for others. If we would do no Action without it, it must be the Source of the one Sort of Actions as much as the other.

P. You are right. We saw this Truth before, by Way of *Induction*, or an enumeration of Particulars: And now we see it by a contrary Sort of Argument. The Desire of Existence in a *Reflecting Being* is never bounded; but (as has been said) extends itself formally into the Desire of endless Existence. Man having this endless Desire, is susceptible of that Affection in his Nature which we call *Sympathy*, and which may be explained by *Fellow-feeling*, or *Compassion*. All Sympathy therefore supposes the *feeling* first in ourselves; or *Fellow-feeling* is founded upon *Self-feeling*.

M. I conceive it: Sympathy must be a Contradiction without this; as if it were said, we felt the endless Desire of Existence with another, which we do not feel with another.

P. From this Sympathy then (which is thus founded on the previous Desire, or Self-feeling) Man becomes social, friendly, and benevolent: He exercises Acts of mu-

tual Forbearance, he defers the immediate Gratification of his Pleasures, and undergoes Pain for the Sake of others: Because in this large Prospect, (and in this Prospect only) he sees there is Room for the rational Desires of all Beings to have their full Consequence, and for the Happiness of all to be made consistent.

M. I am in love with this Deduction; one Part of it falls in naturally with another, so that it seems firm and compact. And it is doubly agreeable to see, that this Desire of endless Existence, so strong in the Nature of Man, is the Foundation of all social Virtue; of all great, brave, and generous Actions. A Passion so predominant in our Nature must be good in its Consequences.

P. After this therefore you will easily perceive, that those Philosophers, who lay the Foundation of Virtue in the social and benevolent Nature of Man, or in the Beauty of Virtue, or the Harmony of virtuous Actions, independent of the Immortality of the Soul, and without any Regard to ourselves, raise a Structure without a Basis. If a Man be indifferent about being *Something* or *Nothing*, he would hardly exert those Efforts out of Benevolence to others, which

which he would not exert for the Sake of his own *Being* : Or the Existence of others could not be a Motive of Action to him, if his own Existence were none.

M. This is very true : But their Structure seems chiefly without a Basis in this Respect, that Man could have no Benevolence, or Sympathy, without a Self-feeling *. Thus they lay the Foundation of Virtue in the Benevolence of Man, but they leave this Benevolence without a Foundation : Therefore they leave Virtue without a Foundation.

P. Or we may consider the Case thus, if Benevolence be our Duty, it is but our Duty in Consequence of Existence, and not in Consequence of being Nothing. As Benevolence therefore supposes Existence, it supposes our Endeavours for the Preservation of our own Existence, or a Love to ourselves in the first Place ; otherwise the Exercise of that Virtue, and indeed of all Virtue, becomes contradictory. So absurd is it to make social Virtue, or Virtue under a

* We may observe here in passing, that the Goodness of God to his Creatures is of a purer Nature than the Benevolence of Man to Man ; as the Divine Bounty cannot proceed from a Fellow-feeling, or Fellow-suffering, but is perfectly free and gratuitous.



ny Denomination, independent of Love to ourselves, or of Desire of Existence!

M. That is the Notion I had; and it gives me the greater Satisfaction, as I find it so agreeable to my Nature.

P. No Man therefore could die for his Country, or for the Sake of Virtue, without a Desire of Existence, at the same Time that he parts with Life: From which let the Conclusion be drawn.

M. O pleasing Conclusion! It is this; The Exercise of Virtue proceeds on the Supposition that Existence is not confined to Life, or reaches beyond Death! From what you have said, it is plain that the Exercise of Virtue, has the Support of Society becomes otherwise contradictory. The rational Nature itself, and the Practice of Virtue, leads us silently by the Hand to this Truth, and lands us, lands the most illiterate virtuous Man, on a happy Immortality, without the Noise of Controversy and Arguments. —

P. It is said by a great Author, *Mathe*, That we ought to give up our very Being for the Sake of our Country. But first, Being is not a Thing so easily to be got quit of, though we should be willing to
part

part with it: Our Being is not at our Disposal. And then, if we be indifferent about Existence or Non-existence, that is, if we have no Love for ourselves, this can be no Virtue: We part with a Thing for which we have no Value. Where again we see that taking away Love to ourselves takes away the Nature of Virtue. Besides, if this be a Duty incumbent on any one Member of the Society, it is a Duty incumbent on every Member in it, to part with Being; and ——— for the Sake of what? The Society consists but of all its Members. It is absurd to make that the Duty of *every one*, which would ruin the *Whole*: It is foolish to suppose that the Non-existence of any Being might be made the Condition on which the Safety of the Society depended: And it is begging a material Question to suppose that when a Man dies for his Country he becomes Nothing.

M. All this is obvious from what we have said.

P. In fine then, as the Practice of every Virtue supposes Existence, the Obligation to the Practice of every Virtue supposes, in the first Place, the Obligation to love and defend our own Existence, to

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which you see we are so strongly carried by our Nature. Hence the Beauty of Virtue, or Harmony of virtuous Actions, or any other Pretence that can be devised, could fix no Obligation upon us without this Foundation. The Notion *that Virtue is its own Reward* hath been long boasted: But this constitutes no Obligation. If a Man is willing to part with the Reward, he will be under no Obligation to the Practice. The virtuous Man rather will be most in love with Existence, or Immortality; because it is of more Value to him than to another: He will likewise do most for the Sake of it, and therefore be most social and benevolent, for the Reasons I just now mentioned; because, on this Supposition, he sees there is Room for all rational Desires to be gratified, and the Happiness of all to be made consistent; a Condition that cannot be met with again, if we exclude the Immortality of the Soul. And to call this a *selfish, or interested Scheme*, by Way of Contempt, and the contrary Supposition, which must have very different Effects, the *benevolent Scheme* is (to say no more) a changing the Names of Things.

M. Since

M. Since the Author of our Nature has so constituted the Actions of rational Beings, that the Man who acts most for his own Interest, acts most benevolently toward others at the same Time; the Attempt to make *Interest* and *Virtue* clash, or to settle them on separate Foundations, can never be justifiable.

CLIV. From all this I am satisfied, it must be a great Comfort to the Life of Man to consider, that the Desire of Immortality is the Source of all Virtue; that our Prospect of a *Futurity* is our only rational Security at present. A Desire which has such salutary Consequences cannot be implanted in our Nature in vain, nor remain unsatisfied. — But pray tell me now, is it possible that a Nation of Men denying the Being of a God, and the Immortality of the Soul, could subsist together in a Society, upon their own Principles? This I the rather ask, as the Thing seems to be supposed *Fact*; and yet, if we have reasoned right, it must be impracticable.

P. This you may easily satisfy yourself about: For, if you remember, when we considered the necessary Existence of a Deity,

we

we found that a Being of infinite Power, Knowledge, Goodness and Justice; or (to express it in fewer Words) a Being of infinite Perfection, was necessary; since a Cause without Power and Knowledge (that is an ignorant and impotent Cause) could not have produced such a Being.

M. I remember it distinctly; and therefore, that an infinitely perfect Being must either exist necessarily, on the one Side, or imply a Contradiction to exist, on the other; there is no Medium, since the Cause of such a Being is so strongly repugnant.

P. So we found it. — The denying of such a Being therefore is equal to affirming the Impossibility of Power and Perfection in any Degree?

M. It is: The same Argument repeated over again shews *absolutely*, that if Power and Perfection be not necessary they must be impossible in any Degree; because they could not start up from nothing, or from their Contraries, which are only *mere Negations*. And then it shews that, if Power and Perfection be at all necessary, it must in an unlimited Degree: For, as Impotence and Imperfection could not produce Power and Perfection, no more could they limit these.

these. Impotence, as we said, could do nothing against Power, nor Ignorance against Knowledge. Therefore it is plain, that denying a Being of infinite Perfection is affirming the absolute Impossibility of Perfection in all Senses.

P. The Atheist therefore absolutely denies the Possibility of Power, Knowledge, Justice, Truth, Goodness, and every Perfection; since he does not leave a Difference in Nature between Perfection and Imperfection.

M. This is most unnatural and shocking! Yet the Consequence is plain. He takes away the very Foundation of Perfection, and therefore cannot leave a Difference between it and the Negation of it; for all is the Negation of it.

P. He takes away, by this Means, the Difference in Nature between *Justice* and *Injustice*, *Right* and *Wrong*, *Virtue* and *Vice*, *Truth* and *Falshood*?

M. He does indeed; because Justice, Truth, Goodness, &c. cannot be the Affections of *fixed Matter*, *Emptiness*, *Chance*, *Impotence*, *Ignorance*, or any thing he leaves in Nature.

P. From

P. From this then you may see, that a Nation of Men denying the Being of a God, and the Immortality of the Soul, could not subsist together in a Society on their own Principles; their fundamental Principle, being destructive of all other Principles, takes away the Difference between Right and Wrong, Just and Unjust; in a Word, tears up all the Laws of *Government* by the Roots. And though the gross of Mankind do not go thus philosophically to work, to shew that the Difference between Virtue and Vice is taken away by the Principles of the Atheist, yet (as all Men are ingenious enough to reason on the Side of their Inclinations, and the worse their Inclinations, the more ingenious) they readily enough draw an equivalent Conclusion in Practice. "If there be neither God nor Religion (say they) nor a future State, we may do what we list: If we can by Force or otherwise, secure our selves from Men, who have contrived these Notions, all is as well with us as with others, nay better." These are the parallel Arguments of every Ruffian, how ignorant soever. There is such a strong Relation in Nature between Justice and the Punishment of Vice, that

Atheism

Atheism leads the most unlearned Mind to the Prospect of Impunity.

M. This is terrible Work! But pray what says the Author, whom you called the Apologist for Atheism, to all this?

P. He makes no Difficulty to suppose, That Atheists might live together in Society, provided they had good Laws, and those severely put in Execution; which he observes, is necessary in all Societies, as well as among Atheists*.

M. On what Principles should these Laws be founded?

P. He does not say.

* Mr. Bayle says (*Pensées Diverses* §. 161.) “Après toutes ces remarques je ne ferai pas difficulté de dire, si l’on veut sçavoir ma conjecture touchant une Société d’Athées, qu’il me semble qu’à l’égard de mœurs, & des actions civiles, elle seroit toute semblable à une Société de Payens. Il y faudroit à la vérité des Loix fort severes, & fort bien executées pour la punition des criminels. Mais n’en faut-il pas par tout?”

And again (§. 172.) “On voit à cette heure, combien il est apparent qu’une Société d’Athées pratiquerot les actions civiles & morales, aussi bien que les pratiquent les autres societez, pourvû qu’elle fît severement punir les crimes, & qu’elle attachât de l’honneur, & de l’infamie à certaines choses.” Could Vice be branded with greater Infamy than at present, when the national Principle denied the Difference between Virtue and Vice?

M. They

MATHO: or, The

M. They could not be founded on the Atheist's own Principles; for those take away the Difference between *Right* and *Wrong*, and tear up (as you said just now) all the Laws of Government by the Roots.

P. Certainly they could not.

M. That is to say then, Atheists might live together in Society, provided they were forced to live contrary to their own Principles? Is it not?

P. It is.

M. But who should force them to live contrary to their own Principles? Or put the Laws severely in Execution? For by Supposition, there are none except Atheists in the Society. Or does he suppose that they would choose the chief Magistrate of a different Persuasion, and give him an armed Force sufficient to oblige them to act contrary to their own Tenets?

P. He does not consider the Thing in that Light.

M. How doth he consider it then? Does he suppose that they would so far relinquish their own Scheme, as to borrow the Laws of their Neighbours, who own God and Religion?

P. He

P. He enters not into the Discussion of any of these Particulars.

M. This seems to be a notable Piece of Sophistry. A Society of Atheists could neither get a System of Laws at first; nor could these Laws, though once established, be put in Execution, but in Contradiction to their own Principles.

P. He supposes the *Ax* and *Gallows* would do all.

M. The *Ax* and *Gallows* might head and hang: But he can never suppose that the Society could have a Right to punish, upon their own Principles, since all Actions, by these, are equally good, or equally bad. And to punish on no Principle is Murder. If they could have no Laws, they could have no Punishments among them.

P. They might agree to this *by Compact*.

M. Under what Sanction? for an *Oath* has no Signification on the Atheist's Principles. Or what Security could Men give, that they would act contrary to their Principles and Belief?

P. The Thing indeed is repugnant in Nature. They could come under no possible Obligation of observing the Conditions agreed upon, except their own Interest: And

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Interest would be as great an Obligation for breaking the Contract, as for observing it.— This whole Affair, *Matho*; has quite another Aspect, when considered narrowly, than when only looked upon at a Distance; nor are we aware how much Society owes to Religion. —

M. How could a Judge determine between contending Parties? Witnesses could determine nothing: An Oath is as ridiculous in this Case, as the former. Men could not swear by God, who deny there is a God; nor by their Faith, who believe nothing; nor on their Truth, who deny the Difference between Truth and Falshood. — By what sort of Engagements could a Man be bound to another for the Performance of any thing? Why should one Man believe another, if it were that other Man's Interest to deceive him? Or could Men become more honest, because they believed nothing of *God*, *Religion*, and a *future State*? — Must the Society always be in a State of War with their Neighbours? For we cannot conceive how they should enter into Treaties, or Alliances of any Sort. — What is said to all this?

P. Not a Word by this Author, whatever may be done by others.

M. Have you any thing to say to it?

P. I foresee what Answers you would make; so 'tis needless to spend Time: Only

CLV. You take no Notice of the Observation, that Laws are as necessary in every Society, as they would be in a Society of Atheists.

M. Not so necessary, I hope. — But on what Principles are these Laws founded? — Or what sort of Actions are they designed to restrain? If a Man *steals, murders, swears falsely*, he acts against his own Profession; he acts, I suppose, consistently with Atheistical Principles: Is it not so?

P. Undoubtedly: For if the same Man were an Atheist, he could not act better, because he had not good Principles; but might act worse.

M. Would any Vice in Life cease, if Men became Atheists?

P. The same irregular Passions remaining, Vices must then be multiplied: For good Principles are of great Service to Society.

MATHO: or, The

M. All Laws whatever then, for the Support of Society, are made against Atheistical Principles and Practices. As these Principles would tear up Laws by the Roots, all Laws are levelled against them. And is it not a fallacious Way of Reasoning, since every where there is a Necessity for Laws to bear down the Practices arising from Atheistical Principles; since both the Laws, and the Profession of contrary Principles, can hardly restrain these Practices; that therefore a Society of Men, having no other Principles, might subsist by good Laws impartially executed?

P. I do not pretend to defend this Author; yet he has a Salvo for the Difficulties you mention.

M. What is it?

P. Being pressed with these Absurdities, he retreats to another Defence. He owns Atheists could not live according to their own Principles, but contends, that Men do not act according to their Principles.

M. According to what else?

P. He avoids being particular; but from comparing several Places together, it may be gathered, that he means, *Humour*, the prevailing Mode, a particular Passion, De-

fire of Praise, Interest; with other Motives of that Kind †.

M. Does he make such Things the Rule of Action?

P. He says, Men make them the Rules of their Actions.

M. And thence he infers, that the Atheist needs no Laws at all?

P. That is the only Inference that could serve his Purpose: But he avoids such an open Absurdity.

† Mr. Bayle speaking of an Author who had shewn that, on Atheistical Principles, Reason, civil and natural Obligations, Justice and Virtue, were only but Words void of all Sense, adds ——— “ Il le prouve fort judicieusement; mais parce qu’il n’a pas pris garde à une chose que je crois avoir démontrée, sçavoir que les hommes ne suivent pas ~~deux~~ principes, on lui peut objecter avec raison, qu’il n’a rien prouvé dans cet endroit-là.” §. 181. And again, §. 176. ——— “ Car s’il est vrai que les persuasions generales de l’esprit ne sont pas le ressort de nos actions, & que c’est le temperament, la cûtume, ou quelque passion particulière que nous determinent, il peut y avoir une disproportion énorme entre ce que l’on croit, & ce que l’on fait.” ——— And in another Place, having reckoned up a great many Actions, which, he says, a Society of Atheists would observe, he assigns this Reason for it. ——— “ Soit parce que le desir d’être louez les pousseroit à toutes ces belles actions, qui ne sçauroient manquer d’avoir l’approbation publique; soit parce que le dessein de se menager des amis & des protecteurs, en cas de besoin, les y porteroit.” ——— §. 172.

A a 2

M. This

M. This is almost above Belief! —

Then there is no need of Laws at all for his Society of Atheists: This will do the Business. Nor are Principles necessary in any Society: If this be a good Reason why a Nation of Atheists stood in Need neither of Principles nor Laws, it will be a Reason for all Societies whatever. But (not to take Notice that *Humour*, the *prevailing Custom*, *Passion*, or *private Interest*, are strange Things to trust the Interests of Society to) his Reason itself seems to me as false as any thing can be: For whatever a Man acts from, that is his Principle of Action.

P. You are certainly in the right. If he had said, Men do not act according to their *Profession*, there had been but too much Ground for the Observation: But a Man never acts contrary to his Principle; the Motive of *Interest*, *Praise*, &c. is the Principle of such Actions as proceed from them. The Profession of a *Pick-pocket* is Honesty: But it would be ridiculous to suppose, that he had an honest Principle. Therefore it is of the greatest Importance to Society, that Men's Principle be just and rational. *Principle* is the Source of a thousand virtuous Actions, the Practice or Omission of which the

the Laws could neither enjoin nor punish. Would Men act according to right Principles, the Laws would have little to do. In a Word, there is as great a Difference between one who acts right for fear of the Laws only, and one who acts right from Principle, as between a cunning Rogue, and an honest Man. — But I hope we have now done.

M. Pray don't be so impatient,

CLVI. One Particular occurs to me, which I wish this Author had considered; namely, in what Manner a Society of Atheists were to breed up their Children: Whether they were to discover to their Children their whole Principles at first; that there was neither a God, nor Religion, nor a future State; that whatever they might hear said concerning the Creation of the World, the Government of an *Almighty Being*, Punishment of certain Actions in and after Life, &c. were but mere Fictions: Or, that Parents might have their Children more obedient and tractable, if they were to educate them in the contrary Belief. For, as far as I can see, there are unanswerable Difficulties, let us make which of the Suppositions we please?

A a 3

P. He

MATHO: or, The

P. He says nothing concerning that Matter.

M. Then he has considered his Subject very lamely. One who would shew that Atheism is consistent with Society, ought to consider all Things necessary to the Continuance of the Society: And there is nothing more essential to this, I believe, than the right Education of those who are to constitute the Society after we are gone. — Or perhaps you are amusing me all this while with an imaginary Author; since it is hardly to be supposed, that any Man would throw out such silly sophistical Stuff, and so pernicious too in its Consequences.

P. I am not amusing you. You cannot converse long in the World, till you meet with the Book, or perhaps have it recommended to you, And whatever Stuff this may be, or however lamely the Author may have treated his Subject, he hath filled three or four Volumes with it.

M. On what Pretence?

P. On the Discussion of this remarkable Point, *That Atheism is not so bad as Superstition.*

M. The whole Design seems to be absurd, and the Handle affected, The Atheist

is

is the universal Parricide — of God and Man, if I durst so say; at least in his Intention. It is not the Tendency of Superstition to subvert Society; if I remember rightly what I have heard concerning the *Ægyptians* and other Nations. But let it be as much worse than Atheism as he pleases; it no way alleviates one bad Thing, that another is worse. It never came into any Man's Head, to run a Parallel between a *Murderer* and an *Incendiary*; or to extenuate the Crime of the first, because something worse might be named.

P. I am of your Opinion: Yet the Author says once or twice a severe Thing against Atheism too.

M. With what Design?

P. He makes a Merit of it, when he is charged with Partiality. — But the great Hurt, *Matbo*, arising from such Performances (which those Authors either do not consider, or do not regard) is, that though Atheistical Principles are ashamed to shew themselves, Atheistical Practice is open and confessed: For, as you rightly observed, the restraining of such Practices is the great and chief Design of all Laws: Or what other Name can you give to the *Highway-*

A a 4

man,

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man, the Robber, the perjured, the cunning Oppressor, the Blasphemer, &c. than a practical Atheist? How many Crimes, think you, take Birth from a secret denying the Justice, the Power, or the Knowledge of the Deity?

— In short Atheism takes off the Guilt of every Villainy that ever was, or ever can be perpetrated. No Principle else offers such an universal Invitation to all Wickedness. And the endeavour to take off, or lessen the Horror every Man ought to have of such Principles, is an Attempt a sober and considerate Person will never be guilty of.

M. I own the Attempt seems as unaccountable to me as Atheism itself. But if a Nation of Atheists could not subsist, how is it possible for them to have subsisted, as those Authors say?

P. *Cicero* observes, that a Company of Robbers could not subsist, but on a Principle of Justice among themselves: We have not now Time to consider these Things farther; only as the Observation is unexceptionable, the Application is easy; *viz.* That a Nation of Atheists could not subsist, but on Principles contrary to their Belief. As to the real Existence of such Nations, it is remarkable what the Author we have been speaking

speaking of says, with Respect to the Accounts we find in Books of Travels; which is to this Purpose: That though we may think it an undoubted Truth, that the *Part* is less than the *Whole*, and that Happiness and Pleasure are the only Objects of Desire in the Nature of Things; yet we should be forced to give up these two Maxims, however certain we may imagine them, if in any Corner of the Earth the *Whole* were found less than the *Part*; or if Men were found, who *loved Misery*, merely because it was Misery *.

M. That

* — “ Mais quelque évidentes que puissent être ces deux maximes, il les faudroit abandonner, si l'on decouvroit dans quelque coin de la terre *un tout plus petit que sa partie*, & quelques hommes qui aimeroient leur malheur en tant que malheur.” Continuation des Pens. Divers. §. 6. To own first that these Maxims are self-evident, and at the same time to suppose that if a Traveller found them false, we should be forced to give them up, is just saying, if a Traveller found what is impossible here to become a Possibility on the other Side of the Globe, we must give up the Distinction between *possible* and *impossible*. I should rather venture to doubt the Truth of the Relation. It is almost equal to this, that in certain Islands, three or four hundred Leagues from the *Philippine* Isles, the Inhabitants are rank Atheists, without the least Sign of the Knowledge of a God: And yet they believe the Immortality of the Soul, a Heaven and Hell, and Pleasures or Torments in an After-

M. That is to say, if an Impossibility were found Matter of Fact! we should then

After-State. And then Mr. Bayle adds — “ Il ne faut pas combattre ceci pas des raisons de metaphysique. Ces sont *des faits* contenus dans une *Histoire très curieuse* publiées depuis peu par un Jesuite celebre. Ibid. §. 14. One might ask here, how these Islanders should come by the Notion of the Immortality of the Soul, of Heaven and Hell, &c. without the least Idea of Religion? For, “ Ils n’avoient pas la moindre idée de Religion.” It is as if he had said, A Man might have the Notion of a *Part*, without having the Notion, that it was the Part of a *Whole*, or of any thing greater. A little after Mr. Bayle owns that the Missionaries of *China*, who all boasted to have searched the ancient Records of the Country, contradicted each other concerning the Religion of the *Chinese*; some affirming that they acknowledged a God, and others that they were all Atheists to *Confucius*’s Time. — “ les uns avec le Pere le Comte la font orthodoxe, les autres prétendent que l’Atheisme a regné dans la *Chine* jusques à *Confucius*, & que ce grand Philosophe même en fût infecté.” §. 28. In one Place, Mr. Bayle, having shewn at great length, that Religion once introduced into the World, can never again be lost, concludes, that as there are Nations which have no Religion, they must have been in that State from their first Origin. — “ Comme donc il y a des peuples qui n’admettent aucune Divinité, il faut conclure qu’ils ont été dans cet état des leur premiere origine, &c.” §. 6. And again, he says, according to his Principles, and the Christian Religion, it follows, that there never was a Nation without Religion. — “ Ne me dites pas qu’un Chrétien se peut épargner une partie de la peine, puisqu’il sçait que la Religion est aussi ancienne que le genre humain: Car même selon mes principes, il s’en suit de là qu’aucun peuple n’a jamais été sans Religion.” §. 15,

be

be forced indeed to give up all Truth at once. If the *Whole* were found less than the *Part*, all the Demonstrations of *Euclid* would be good for nothing. However one Thing is certain enough from this sort of Argument, That if in any Corner of the Earth a Nation of Men were found to spring out of the Ground, like Coleworts, they would have neither a Name for, nor any Notion of a Deity.—But since an Atheist must deny that Religion is as ancient in the World as the Race of Men; or, since he denies any other Creation than this *Chance-Production*; pray how does he account for the Rise of Religion at first; for its universal Spreading; and why Man is thus naturally a *Religious Creature*?

P. It is impossible to answer all your Questions, *Matbo*;—Such a Creature as Man, so weak, and living in such Dependence, must be religious, if he has but the Power of Reflection: Ignorance therefore, and want of rational Improvement will make him superstitious. As to the first Rise of Religion in the World, the Atheist's Account of it in short is this. That some prudent and wise *Law-Giver* first invented the Notion of a God, and the Immortality of the

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the Soul, to frighten Mortals into an Obedience to the Laws, and to make them more virtuous, and better Members of Society, than the Laws could do: With a good deal more to the same Purpose †.

M. Did one who had never heard of God, or the Soul before, contrive all this?

P. So the Atheist supposes.

M. At this rate then the Atheist owns, that Laws could not bind a Nation of Men, without the Help of Religion,

† See *Sextus Empiricus*, lib. 9. cap. 2. Where he gives the several Atheistical Conjectures concerning the Rise of Religion. The first is, ἐνιοι τῶν ἄνθρωπων προσάντας, ἢ τὸ συμφέρον τῷ βίῳ σκεψαμένους πάνθ' ὁρωμένους ὄντας, ἀνεπλάσαι τὴν περὶ τε τῶν Θεῶν ὑπόνοιαν, ἢ τὴν περὶ τῶν ἐν ἄλλῃ μυθευομένην δόξαν. The Steps of the Invention were, They first made Laws: But these being found insufficient, they contrived the Notion of the Gods, for the more effectual restraining of Vice and secret Crimes, [where, by the way, we may again see, even according to this Original of Laws, that they were first made against Atheistical Practices, and are still necessary on the same Account.] — πρῶτον μὲν νόμους ἔθεντο πρὸς τὸ τὰς φανερώς ἀδικοῦντας κολάζεσθαι· μετὰ δὲ ταῦτο, ἢ Θεὸς ἀνέπλασαν ἐπόπτας πάντων τῶν ἀνθρωπίνων ἀμαρτημάτων τε ἢ κατορθωμάτων· ἵνα μηδὲ κρύφα τολμῶσι τινὲς ἀδικεῖν, πεπεισμένοι ὅτι οἱ Θεοί. κ. τ. λ. The Account *Critias* (one of the *Athenian* Tyrants) gives, is the same. The Place is worth the Perusal of an attentive Reader.

P. He

P. He owns this to be the Experience of prudent and wise *Legislators*.

M. It is enough. The Atheist is certainly the most barbarous Parricide, first to allow the indispensable Advantage of Religion to Society, and then to tell the World, it is all a Cheat! —

P. Here then you again see the Necessity of believing a future State, in order to our subsisting in this. An infinitely perfect Being, the Author of our Nature could not have so constituted us, as to make the Belief of a Lie necessary to our living together here as rational Creatures. Every thing in the Nature of Man, when it is truly examined, points to the Continuance of our Existence after Death, and shews the manifold Relations, which join the present to a future State. These Relations stretch out to Ages that can never end, and carry on the Existence of rational Beings even to Eternity. The Desire of Existence (you saw) is the Foundation of all our Desires: A happy or pleasant Existence is the only consistent Object of Desire in the Nature of Things: The Desire of rational Existence and Happiness, in Opposition to sensitive Pleasure, must be rational and consistent, by the Terms: This

Desire

Desire can never cease, more than rational Pleasure and Happiness can ever disgust and cloy : It cannot be conceived that the Author of our Nature, and of this very Desire, who is himself an infinitely rational Being, should not satisfy a rational Desire ; or not satisfy it as long as it continues to be, and to be rational ; that is, to Eternity.

M. I see the Argument as strong as Demonstration.

P. These are but some scattered Considerations, *Matho*, concerning the Immortality of the Soul of Man. The Nature of our Discourse, and the Shortness of our Time, will not suffer us to pursue the Subject at just Length, and in a proper Method : But these Hints, and your own Reflections, as Age ripens, will still farther confirm you in this delightful and comfortable Speculation ; which is the main End of all your Studies, all your Application, and in Truth, of all Philosophy. To contract a Habit of rational Pleasure, without this Certainty, would only torture you the more.

CLVII. *M.* That would be a melancholy Situation, while we are in Pursuit of Things of an eternal Nature, to be haunted with

with the constant Fears of losing our own Being. The unreflecting State of the brute Animal would be more eligible.

P. Hence then it must be an equal Encouragement to consider, that we are engaged in Speculations, the Pleasure and Variety of which will never have an End.

M. It must: Wherefore (to return to our former Subject) I now perceive why, in some Parts of our past Discourse, you put off my Questions concerning the Art in the Works of Nature, which is at present inaccessible to us, either because of its Remoteness or Minuteness; till we should be able to discover something that might shew the Accomplishment of our Desires possible.

P. How doth the Possibility of satisfying this Desire of Knowledge now appear?

M. Since we are carried by a rational Desire to contemplate all the Works of Nature; since we can only get such a Taste of this Pleasure here, as to excite and kindle our Desire; and since all our rational Desires must be satisfied; it follows, that *this Beginning* must be continued, till we at length see the Use, and comprehend the Contrivance of all the Miracles of Power and Skill, thro' the wide material Frame. Our interminable
Existence

Existence suits well with such a Design, and shews every thing consistent. Otherwise what a killing Thought must it be, to have a View of being turned down with the Ox, while we have the immense Prospect before our Eyes! To bid an everlasting Adieu to all that which raises our Nature above Humanity, being to share the Fate of the Beasts of the Field! This (let me dare to say it) would be the most studied Cruelty, the most exquisite Torture of the rational Mind.

P. Consider what an Immortality of Ignorance would be, forced upon a rational Being thirsting after Knowledge.

M. You shew me how wisely it is ordered, that our Period here should be but short. The Prospect put off to Eternity would be an eternal pining in Despair. This could not be a Work of Kindness. Nor can eternal Happiness consist in Ignorance: That brings it back to something like the Gratification of Sense. It must be intellectual.

P. You are certainly in the right: We cannot have a consistent Notion of immortal Happiness, unless it be so conditioned. And as it must be *intellectual*, it must necessarily consist in having the Power and Knowledge,
the

the Wisdom and Goodness of the Deity gradually discovered to us. This is the only Source of rational and intellectual Pleasure. The only Source; for there is not another Nature (if I may so say) which we could apply to, or improve by. To this Purpose it is wisely and wonderfully ordered, that we should begin even by the Methods of Sense, 'till, having made the intended Advancement, that Method be antiquated, and the Design come to be pursued in a superior manner. These Wonders in the material Creation were wrought with this View, to initiate the rational Being, and raise it gradually to the Knowledge of *higher and greater Things*. And as was observed before, we cannot conceive any other consistent Design, why the Author of our Nature at all reared the Frame, if not for the Sake and Improvement of his rational Creatures. It is absurd to suppose that he exposed those Works of Power and Skill to inform no Being; and impious to imagine, that he wrought thus to solace or improve himself; as if he had not been sufficiently happy without a material Structure, which he might move and direct various Ways; or, as if he had proposed to attain at last the Perfection

of Art, by Application and Practice. His Goodness only could put him upon the whole Design; and the Design cannot prove abortive.

M. I am satisfied the Deity could not have exposed those Instances of Divine Art for the Instruction of no Beings: In that Case the Habitation of rational Creatures needed no more Contrivance nor Ornament, than the Retreats of the wild Beasts. A Convenience for sensitive Life had been all that was necessary or proper. And if such a World could not be designed for Beings of a sensitive Nature, it could not be designed for the sensitive Nature of rational Beings; nor be applicable to their rational Nature in any other Respect, than by discovering to them the Power and Wisdom of their Creator.

P. Could our Creator then design that we should admire his Power and Wisdom, only as they were displayed on the out-sides of Things; but resolved to conceal from us the internal mysteries of Contrivance and Art, lest we should improve our Nature too much; or admire his Perfections beyond a certain Degree; or come at length to expect more than he could perform?

M. These are impious Suppositions.

P. Or were the external Wonders in Heaven and on the Earth designed to catch the Attention, and kindle up in us a rational *Longing*, with a View only to mock and tantalize our Expectations?

M. That would be the low, malicious Pleasure of a weak Mortal.

P. Or could those Wonders be perceived only by the Methods of Sense?

M. They could as little be perceived as wrought or effected by the Methods of Sense. A material System could no way aid the Soul either to perceive or act: A System of inert Substance limits and confines it in both, and may wholly impede the Exertion of its Powers. This you shewed me before. I have no Doubt remaining. The Deity is above Envy: He could not design to mock our rational Expectations: His Goodness was the only Motive: The Methods of Sense are incompetent: The Soul, when freed from a dead Substance, hath the Limitation taken off: Neither the Subtilty of the Art, nor Remoteness of the Object, can be a Let to a pure Spirit: — But to the Knowledge of what *higher and greater*

Things were the Wonders in the material Universe designed to raise us?

CLVIII. P. And yet Matter, however heightened by Workmanship, is (as you yourself acknowledged before) the very lowest of Things; a sluggish and inert Substance, utterly destitute of all active Power, and capable only of being passive. Wherefore beware lest you imagine, that this dead Substance obtains the highest Rank in the Works of the Creator. Nothing, it is true, could be better fitted to initiate Beings, whose first Informations of Things are from Sense, and to train them up in the Elements of Knowledge and Admiration: But the *external Frame*, the *Case*, can never be of equal Dignity with the Thing for whose sake it was made, nor an equal Instance of Skill and Power.

M. You recall once more to my Thoughts the several Particulars we saw and concluded concerning the Nature of this Substance. Unwrought Matter presents us with the Power of the Deity: But we can turn our Thoughts to no Species of it in the Universe, that has not gone through the Hands of the Artificer.

Artificer. — It is so wonderfully made, to support our Bodies, relieve our sensitive Appetites, and convey the Notice of external Objects to the Soul, by Means of the Senses, that by considering all the Effects, without looking to the *Cause*, or reflecting upon the *End*, Matter is become the Deity of Mankind. — But I likewise saw, that the Soul of Man, and of every Animal, is an immaterial Being; and that the different Structure of the Body, in every Species of living Creatures, is fitted to the various Powers and Capacities of this living Principle. Hence it is reasonable to allow, that the Creator has shewn more Art and Power in making this more noble Being; nor can there be less Variety in the living, than in the dead Part of the Creation.

P. The Works of the Deity, *Mattho*, as we have often said before, constitute a certain *Scale*, or Gradation, which still rises in Dignity. For they are either *purely material*, or *immaterial Substance*, joined to an organized Body, or lastly *pure Spirits*, free from all Contagion of Matter. Since then in the first two Parts of the Scale, there is such an amazing Variety of intermediate



MATHO: or, The

Species, beginning at unwrought Matter, and ascending to Man; it is altogether incongruous, that in the *third Order* there should be no Gradation nor Variety; but that after we have once got above the Alloy and Depression of a dead Substance, we should then have risen to the Supreme Being.

M. It is certainly incongruous that all above the Confines of Matter should be a mighty Blank.

P. The Series of immaterial Beings begins with the very lowest Animals; that is, it borders on the vegetable Kingdom, and rises by innumerable Steps to Man: Now what is there between *Man* and the *Deity*?
— Nothing?

M. The third Order seems to be entirely wanting, and the Scale broke off in the Middle, unless there still remains a proportional Gradation among *pure Spirits*, still rising in Degrees of Perfection.

P. Since then, there are none of the Works of God, but what serve for the Advancement of the rational Nature; none of them secluded or hid from the rational Spectator; what Wonders of Power and Wisdom,

Wisdom, do you think, must still remain, after we have are above the passive Nature of a dead Substance? How much a greater Instance of Power is it, to have bestowed *Power itself*, and various Degrees of it too, upon other Beings, than to have exerted his own Power only on this passive Subject?

M. This I in some Measure conceive, if I compare *self-moving Engines* (as they are supposed) with any common Instrument, which requires the constant Application of the Hand. Though I am aware, that *Clock-Work* hath, properly speaking, no Power in itself. —

P. Or could the Deity have bestowed Power and Agency on Living Beings, only as they were clogged with Systems of dead Matter?

M. Ah! Do not ask a Question so absurd! As if Matter could contribute any thing, by confining, or obstructing the Powers of a living Being!

P. Or could He not have imparted to them Powers above those of the human Soul, without encroaching on his own Omnipotence?

B b 4

M. It

M. It is too much, *Philon*; I see the immaterial, the spiritual, the living Part of the Creation, may rise in Degrees of Power above our Conceptions; yet without being able to approach the boundless Perfections, and self-existent Nature of the Creator.

P. If therefore there must be an infinite Distance between the highest created Nature, and the necessary Perfections of the Deity, the Knowledge of created Beings, or concerning created Things, must fall infinitely short of the Knowledge in the *Divine Mind*. The Connexion of eternal Ideas, which have no Relation to the Existence of any Thing, except the Mind, whose Ideas they are, are many ways, infinite ways, infinite. We may still be advancing in the Perfection of our Nature, and still must be at an infinite Distance from the *necessarily existing Being*.

M. I see that *Necessity* of *Perfection* must infinitely prevent all possible Improvement of Perfection.

P. You express the Disproportion, *Matho*, justly: As an endless Addition of Minutes could never constitute Eternity, nor make the future Prospect less; so it is between

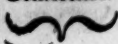
between immortal Beings, still advancing in Perfection, and the Deity necessarily perfect. And in this consists the eternal Happiness of rational Beings, endlessly to acquire new Accessions of Perfection and Happiness, with an infinite Prospect still before them. Thus the Soul must flourish in the Adoration and Love of its *Maker*, through Ages that cannot end, and in the Fellowship of happy Spirits past numbering.

M. Nor does the Certainty of this Prospect less constitute our present Happiness; since these Reasons cannot fail, or yield, in Sicknes, Danger, or Death itself.

And now, *Philon*, I shall put an end to my Questions, and the Trouble I have given you; nor shall I attempt to express in Words the Sense I have of your Friendship: But while I remember the noble Truths you have shewn me, and the Dignity of the human Soul, I cannot forget the Man who first led me through these pleasing Speculations.

P. This is too much, *Mattho*, to your Friend. Were it true, that I had been so serviceable to you as you speak of, my
Pleasure

Tenth
Conference.



Pleasure must be at least equal to yours. But you owe the greatest Part of these Discoveries to your own *Genius*, the Happiness of which I have often admired in the Course of our Conferences; for you discovered the Reasons of Things yourself, and generally prevented what I had to say.

ANNO-TA-

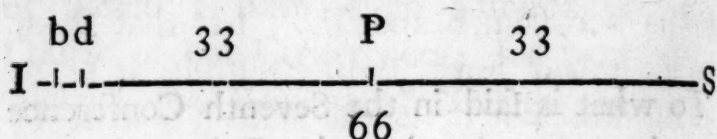
ANNOTATION

To what is said in the Seventh Conference above, concerning the Point of equal Attraction between the Sun and any of the Planets; or *that Point*, where if a Body were placed, it should gravitate neither to the Sun, nor to the Planet.

AS the Method proposed in the Note at the End of the *Latin Pamphlet*, for enquiring into the Sun's Parallax, and approaching, if possible, nearer the Truth, has not, I humbly think, been sufficiently considered; I beg Leave to translate the Note here, and make it a little plainer, that what is proposed may be seen with the less Trouble: Hoping no one will be offended, since I do it with no View to *contradict*, or *find Fault*, but only for the Sake of what I take to be the Truth.

The Method of finding out the Point of equal Attraction between the Sun and any Planet, the Quantity of whose Matter is known with Respect to that of the Sun, will

will easily appear from an Example. Let the Line IS represent the Distance between *Jupiter* (for Instance) and the Sun.



Upon the Supposition that the Sun's Distance from the Earth is about 21000 of the Earth's Semi-diameters, the Quantity of Matter in the Sun is to that in *Jupiter* nearly as 1089 to 1; which is easily discovered from what is shewn in N^o. 131 above. The Square Root of the Number 1089 is 33. Now at an equal Distance from both Bodies, or at the middle Distance P between their Centers, their attractive Forces are as their Quantities of Matter, 1089 and 1: That is, the Sun's Attraction is there 1089 Times stronger than *Jupiter*'s. Let Ib be $\frac{1}{33}$ part of IP, (or $\frac{1}{66}$ Part of the whole Distance IS;) and *Jupiter*'s Attraction at b will be 1089 Times greater than it is at P; for it is inversely as the Squares of the two Distances Ib and IP. Therefore *Jupiter*'s attractive Force at b, and the Sun's at P must be equal. Then since both Forces decrease

crease as the Squares of the Distances increase, they must come to be equal again, or balance each other, at some common Point between b and P. Let that Point be d. And since *Jupiter's* Force at b, is to his Force at d, as the Sun's Force at P, is to his Force at d; (for as the Antecedents are equal, so are the Consequents;) the Squares proportional to these Forces must also be proportional; that is, I d Square is to I b Square as S d Square is to S P Square; and, by Inversion, I b sq. : I d sq. :: S P sq. : S d sq. And (by *Eucl.* VI. 22.) I b : I d :: S P : S d. Hence, making $bd = x$, it will be, $1 : 1 + x :: 33 : 65 - x$ or $33 - 33x = 65 - x$. Whence bd or $x = \frac{32}{34} = \frac{16}{17}$. Thus 'Id', or $1 + x$ is equal to $\frac{31}{17}$ Part of the whole Distance between the two Bodies, and $\frac{16}{17}$ of $\frac{1}{17}$ Part: But it cannot be equal to $\frac{2}{17}$ Parts, or $\frac{1}{17}$ Part of the whole Distance. For if I d were double I b, S d would be double S P; that is, d would coincide with I, which is repugnant.

Hence we may form this general Rule concerning the Point, where the attractive Force of a Planet is equal to the attractive Force of the Sun, *viz.* That it is more remote from the Planet than that Part of
the

the Distance between the Sun and it, which is expressed by a Fraction, whose Numerator is unit, or the Quantity of Matter in the Planet; and the Denominator is twice the Square Root of the Quantity of Matter in the Sun: But it can never come to be equal to two such Parts.

From this we may easily see that the Point of equal Attraction between the Sun and this Planet falls a great Way without the Orbit of his utmost Satellite. If the Earth's Distance from the Sun be 21000 of its own Semi-diameters, *Jupiter's* Distance from him is about 5264 of his Diameters. And supposing the *Point of equal Attraction* between him and the Sun $\frac{1}{3}$ of this Distance, that comes to about 159 of his Diameters: Whereas his outermost Satellite is distant from his Center only $12\frac{2}{3}$ Diameters. All his Satellites therefore lie far within the Limits of their Primary's stronger Attraction; so that they must have been removed to a vast Distance from him, if they had revolved about the Sun separately, as primary Planets; as was observed above (N^o. 116.) The same Way it may be found that the innermost of *Saturn's* Moons must have revolved at a greater Distance

stance from his Center, than 84 Diameters of his Ring, to have been without the Limits of his prevalent attractive Force; whereas the outermost of them is not above 12 of these Diameters removed from his Center. Which shews us clearly that the Bounds of the Solar System must have been greatly enlarged, had the 9 Satellites of those two Planets revolved immediately about the Sun as primary Planets. *Saturn's* Satellites, for Instance, must have been removed, not only without the Limit of equal Attraction between the Sun and him, but the lowest of them must have revolved at a far greater Distance from *Jupiter*, than *Saturn* himself now revolves: Since if *Jupiter* disturbs them at present, notwithstanding the attractive Force of their Primary, he must have drawn them quite down then, when nothing but their centrifugal Force kept them in their Orbits.

This Calculation proceeds on the common Supposition, that the Sun's *Parallax* (or the Angle which the Semi-diameter of the Earth subtends at the Sun) is 10 Seconds; and therefore that the Distance of the Earth from the Sun is about 21000 of its own Semi-diameters. But when I endeavoured

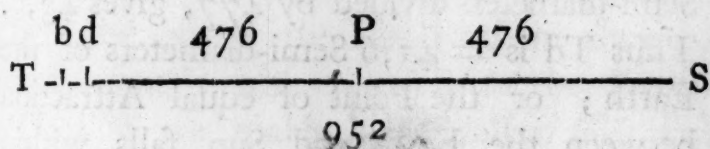
deavoured to apply the same Argument and Calculation to our Moon, in order to discover how far she was within the Limit of equal Attraction between the Sun and Earth, I was surprized to find, that, on this Supposition, she must revolve a great Way without that Limit. This made me suspect something not commonly attended to, which will prove to us (I still humbly think) that the Distance of the Sun cannot be near so great. However, I shall give the Calculation itself, that it may be examined.

If the Sun's Parallax be $10''$, or rather $9'' 54'''$, his mean Distance from the Earth will be 20797,5 of its Semi-diameters; and the Quantities of Matter in the Sun and Earth will then be as 277000 and 1; by what is said above, N^o. 131. For since the Moon's periodical Time is 655 Hours 43 Minutes, or 655,716 Hours, the Square of it will be 429963,472656: And the Square of her periodical Time, if she revolved at the same Distance from the Center of the Earth as *Venus* does from the Center of the Sun, would be 6601084467278. *Venus's* periodical Time is 5393 Hours; the Square of which is

29084449

29084449. And the Quantity of Matter in the Sun will be to the Quantity of Matter in the Earth inversely as the Squares of the periodical Times of two Bodies revolving about them at equal Distances: That is, as 6601084467278 to 29084449, or as 277000 to 1. This I have set down, that any ingenious Person, tho' a Stranger to these Things, may satisfy himself, by going through the whole Calculation, if he has a Mind.

The Square Root of 277000 is 476, neglecting the decimal Parts. Let the Line



TS represent the Distance between the Centers of the Earth and Sun. At the middle Point P between their Centers the Sun's Attraction is 277000 Times greater than the Earth's. Let Tb be $\frac{1}{476}$ Part of TP, or $\frac{1}{952}$ Part of the whole Distance TS, as before; and the Earth's Attraction at b will be 277000 Times greater than at P; or it will be equal to the Sun's Attraction at P, for the Reason assigned above. Let d be the common

mon Point between b and P, where they will again be equal; and then, as in the former Example, $Tb : Td :: SP : Sd$, or (making $bd = x$) it will be, $1 : 1 + x :: 476 : 951 - x$. Hence $476 + 476x = 951 - x$; and $x = \frac{475}{477}$. Therefore $Tb + bd$, or $1 + x$ is equal to $\frac{1}{952}$ Part of the whole Distance $TS + \frac{475}{477}$ of $\frac{1}{952}$ Part of it; but cannot be equal to $\frac{2}{952}$ Parts, or $\frac{1}{476}$ Part of it.

Since Td , or $1 + x$ is equal to $1 \frac{475}{477}$ ($= 1,9958$) of TS , it is $\frac{1}{477}$ Part of it; for $\frac{952}{1,9958}$ is $= 477$. And $20797,5$ Semi-diameters divided by 477 , gives $43,6$. Thus Td is $= 43,6$ Semi-diameters of the Earth; or the Point of equal Attraction between the Earth and Sun falls within $43,6$ Semi-diameters of the Earth's Center.

The Moon revolves at 60, sometimes at 63 Semi-diameters of the Earth from its Center; in which Case it still appears to me that in every Conjunction she would desert the Earth, carried off by the prevalent Force of the Sun; at least, if the Reasoning in the Seventh Conference above be just. For then we must suppose, either that she is carried round the Earth contrary to the common

common Law of Gravity, and on other Conditions than the Satellites of *Jupiter* and *Saturn* are carried round their Primaries; or else that both the Quantity of Matter in the Sun, and his Distance from the Earth, must be different from those last assigned. Let us try therefore what his Distance must be, that this Limit of equal Attraction between him and the Earth may fall without the Orbit of the Moon.

It has been observed before (N^o. 99.) that the greater the Quantity of Matter in the Sun is, or the greater the Distance between him and the Earth is supposed to be, the nearer the Limit where they attract equally will approach to the Earth. Thus if we make his Parallax 6", and therefore his Distance from us 34377 Semi-diameters of the Earth, according to the celebrated Mr. *De la Hire*, by proceeding as before, the Quantity of Matter in him will be to the Matter in the Earth, as 1024820 to 1. The Square Root of 1024820 is 1012, and $\sqrt{\frac{34377}{1012}} = 34$. Whence the Limit of equal Attraction then between the Sun and Earth will be but about 34 Semi-diameters of the Earth from its Center. On this Supposition therefore, the

Force of the Earth to retain the Moon in her Orbit would be little more than a 4th Part of the Sun's Force to draw her from it.

If we make the Sun's Parallax $12''$, the double of the last, his Distance from us will be one half of the former, or 17188 Semi-diameters of the Earth; and the Quantity of Matter in him will be as 128102, the Matter in the Earth being still as unity. The Square Root of 128102 is 357; and $\frac{17188}{357} = 48$. The Point of equal Attraction therefore should be but 48 Semi-diameters of the Earth from its Center; and its Force at 60, or 63 Semi-diameters Distance, would still be much too weak to keep the Moon in her Orbit.

If the Parallax should be supposed 20, or the Sun's Distance from the Earth 10000 of its Semi-diameters; the Quantities of Matter in the Sun and Earth will be as 25230 and 1. The Square Root of 25230 is 158; and the Distance of the Limit of equal Attraction will be $\frac{10000}{158} = 63$ Semi-diameters of the Earth from its Center. Here the Sun and Earth's Forces would be but equal in the Moon's *Apogæum*; whence still there is nothing, no Cause

Cause to make her mount up again towards the Earth's Orbit, after her Conjunction.

Lastly, Let us suppose that the Distance of the Earth from the Sun is only 8000 of its own Semi-diameters; or that the paralla^ctick Angle is $26''$; and the Quantities of Matter in the Sun and Earth then will be as 12917,8 and 1. Here (the Square Root of 12917,8 being 113,6) the whole Distance TS will be expressed by double that Root, or 227,2; and Td, or $1+x$ is equal to $1 \frac{113,6}{114,6} = 1,982$ of the whole Distance. Wherefore $\frac{227,2}{1,982} = 114,6$; and $\frac{8000}{114,6} = 69,8$ Semi-diameters of the Earth. Here perhaps we may stop, having got the Point of equal Attraction between the Sun and Earth, without the Orbit of the Moon: But sooner I think we cannot stop. For when the Sun is at this Distance from us, the Force of the Earth upon the Moon at her middle Distance, is to the Force of the Sun upon her, only as 1,334 to 1: And in the *Apo-
gæum*, it is but as 1,227 to 1; which cannot be too much, that the Earth may have the Command of its own Satellite. We will rather, I believe, think it too little, if we consider an Observation made by
the

the learned Doctor *Halley*, which has a Relation to this Matter.

It hath been observed before that, if the Distance of the Earth from the Sun be 21000 of its own Semi-diameters, its mean Motion will be at the Rate of a 1000 *English* Miles in a Minute. Or, if its Distance were (according to M. *De la Hire*) 34377 such Semi-diameters, it must move at the Rate of 1635 Miles in a Minute. And yet the learned Gentleman just now mentioned thinks it great that it should move at the Rate of 210 Miles in a Minute. In his Observation of *Mercury* in the Sun at St. *Helena*, 1677, he says that the annual Motion of the Earth is so exceeding swift, as far to exceed that of a Bullet shot out of a Cannon, and to be after the Rate of 3 *English* Miles and an half in a Second, which is 210 Miles in a Minute, or 12600 Miles in an Hour *. Here it may not be amiss to consider what the Earth's Distance from the Sun would be, according to this Velocity of Motion in a Minute.

* See Doctor *Harris's* *Lexicon Technicum*, in the Word *Earth*, Vol. I.

The Minutes in a Year are 525969. The Miles then in the Earth's annual Orbit will be 210×525969 , or 1104543490 *English* Miles. The Diameter of the Earth itself is, according to Mr. Norwood's Mensuration, 7967,7 such Miles. But 1104543490 divided by 7967,7 gives us 13862,6. That is, the Miles in the whole annual Orbit, divided by the Miles in the Earth's own Diameter, gives us the Number of Diameters in the whole Circumference of the Orbit, viz. 13862,6; if its Motion be 210 Miles in a Minute. And there will be just as many Semi-diameters of the Earth, in half the Circumference of the Orbit. — The Proportion between the Semi-circle and Radius, is that of 314159 to 100000. Therefore in the present Case it will be, as 314159 to 100000; so half the Circumference of the Earth's annual Orbit expressed in Semi-diameters of the Earth itself, viz. 13863, to 4412,7, the Radius of the Orbit expressed in the same Semi-diameters of the Earth. — Thus, if 210 Miles be the Earth's annual Motion in a Minute, its mean Distance from the Sun will not be above 4413 of its own Semi-diameters.

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This will surprise those who have been accustomed to think of 20000 or 30000 Semi-diameters Distance; and yet any ingenious Person, how little soever skilled in these Affairs, may try this easy Calculation for his own Satisfaction. As 4413 is a great deal less than 8000 Semi-diameters, this lesser Distance will throw the Point of equal Attraction between the Sun and Earth still much farther from the Center of the Earth, than 69 or 70 Semi-diameters; and therefore still farther without the Orbit of the Moon: Which, if we reflect how far the Satellites of *Jupiter* and *Saturn* lie within this *Limit* between the Sun and their Primaries, is not at all improbable. For though we should allow (as is but reasonable) that it is scarcely possible to make such Observations with the last Degree of Exactness, yet it is hard to suppose that this Great Man assigned to the Earth little more than the fifth Part of its real Velocity.

If the Sun's Distance from the Earth be 8000 Semi-diameters, (and it is far more probable that it should be less than greater) the Earth's Motion in a Minute will be 381 Miles. If their Distance should be 7000 Semi-diameters of the Earth; which Dr.

Keill says is the only Thing that is certain, from the several Methods of observing the Parallax ; the Motion of the Earth will be about $333 \frac{1}{3}$ Miles in a Minute. So that Doctor *Halley's* Observation cannot be so wide as the common Parallax of 10 Seconds would make it. But these Things I leave to the Consideration of better Judges.

There were some other Particulars in the *Latin* Note, concerning the Weight of Bodies on the Surface of the Sun, his Diameter and Density, on the Supposition that his Distance from us was 8000 Semi-diameters of the Earth ; which I omit, since it seems plain that his Distance is not so great. I shall only take Notice of one Thing mentioned there, *viz.* That whatever the Sun's Distance from the Earth may be, his attractive Force on the Earth will be such as to hinder it with the Moon to roll round their common Center of Gravity. The only Thing that could make the Earth revolve about this Center must be the attractive Force of the Moon upon it ; which Force must surely have this Effect, if no other Force intervened ; as was observed in N^o. 96. in the Seventh Conference. But if a Force many Times stronger

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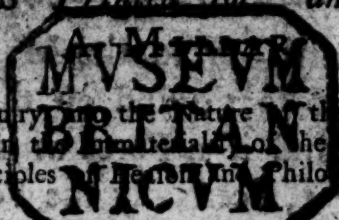
than this detains the Earth, it cannot yield to a weaker in Opposition to such stronger Force. This will be plain if we consider, that the Earth in revolving about this Center must sometimes rise to an absolutely greater Distance from the Sun, and then fall down through a certain Space nearer him : For (as was observed N^o. 97.) it is the common Center of Gravity between it and the Moon, that keeps always at an equal Distance from him. And if the Earth could not make the Moon rise in Opposition to the Sun's stronger Action upon her, much less could the Moon make the Earth rise in Opposition to the same Action. As in that Case we considered the Point of equal Attraction between the Sun and the Earth, so in this we must consider the Point of equal Attraction between the Sun and the Moon. Which Point, if the Earth's Distance from the Sun be 21000 of its own Semi-diameters, is hardly 7 such Semi-diameters from the Center of the Moon; and if the Distance be but 8000 Semi-diameters, the Point of equal Attraction between the Sun and Moon is not yet above 11 such Semi-diameters from her Center. On the former Supposition the Sun's Force

upon the Earth is to the Moon's Force upon it as 76 to 1; and on the latter, as 29 to 1. And if a Force as 29 were overcome by 1, certainly the Force as 28 would be overcome by nothing. There is no explaining, by any *Example* or *Simile*, (as has been endeavoured) how the Earth and Moon may revolve about their common Center of Gravity, in a mechanical manner, unless each of them attracted the other more than the Sun does: That is, unless each of them revolved within the Limit of equal Attraction between the other and the Sun. And even then their Motion about this imaginary Point would be any Thing rather than *mechanical*. I desire any one seriously to read N^o. 97. above, and then to declare whether he thinks that such a Motion, as this is there shewn to be, could either be performed or explained mechanically.

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